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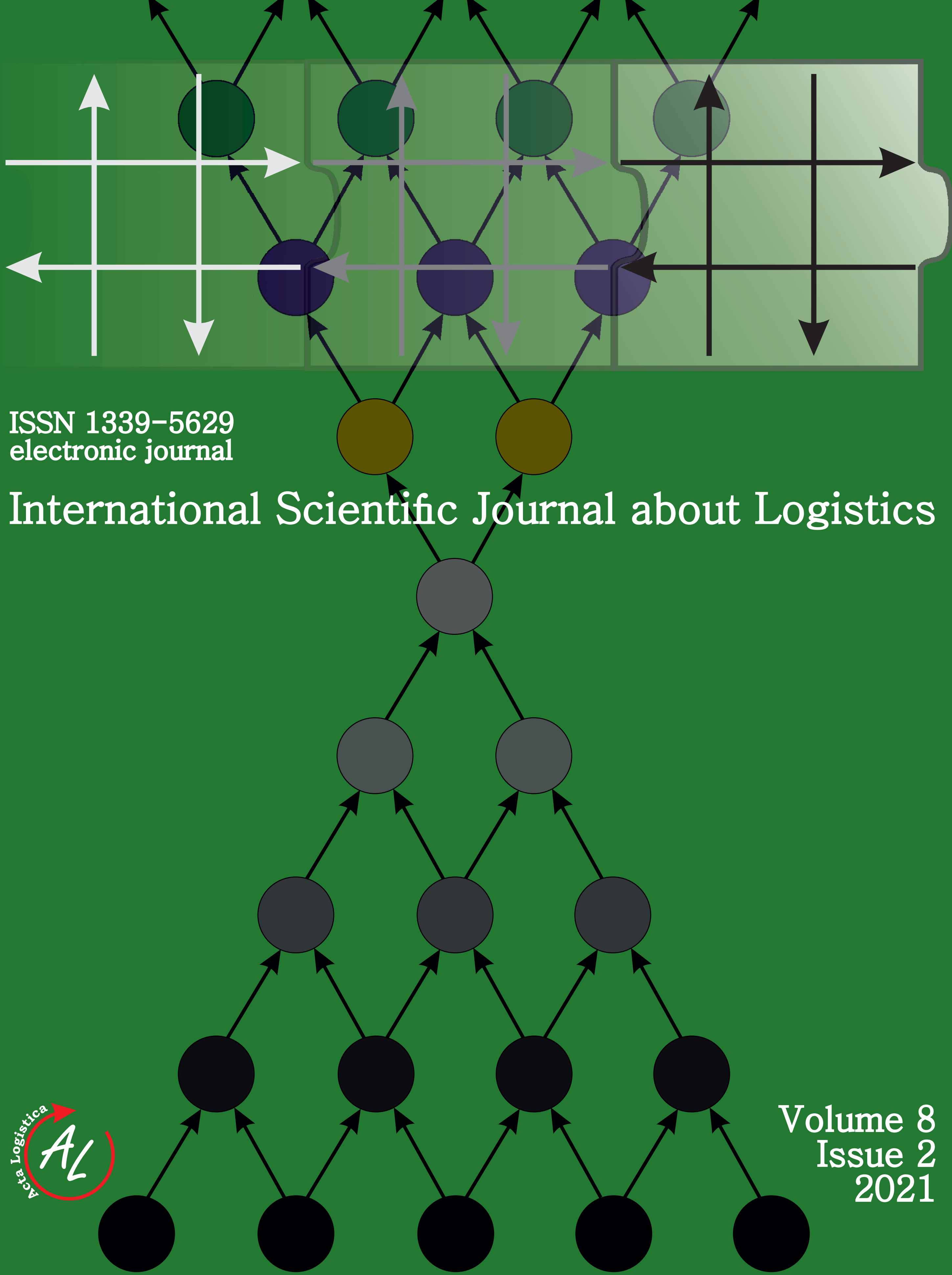

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ANALYSIS OF THE PRINCIPLES OF REVERSE LOGISTICS IN WASTE MANAGEMENT

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Keywords: reverse logistics, waste management, semi-submersible containers, economic and environmental advantages
Abstract: The goal of mentioned contribution is to moderate the unwanted effects of economics on environment in the form of more purposed economy with material sources from recycling, collection, separation and processing of returnable products. It is a global trend nowadays to lower waste production and to minimize effects on the environment. We are going to deal with effectiveness of partly underground containers in Slovakia and new trends about possibilities of other uses of PET bottles. The article deals with the analysis of whether the level of waste management services is at the required level due to the wide range of services provided within reverse logistics. Article's output is created model of reverse logistics and subsequently analysis of cost effectiveness considering economic aspects entering into the reverse model has been made during its use.

1 Introduction

Reverse logistics is a term for all types of reversely aimed logistically solved motion of goods, waste collection and wrappings from customer to the distributor, possibly producer in order to register a complaint or reuse, recycle or disposal in accordance with the regulations in an ecologically desirable way. Additionally, waste separation, storing of separated waste and wrappings, transportation of waste and wrappings to the users or processors belongs to reverse logistics.

According to Lambert, Stock, Ellram [1]: „reverse logistics deals with removal of waste material, which originates in the process of production, distribution and wrapping of goods. Typically, it is an activity such as securing the temporary storage of these materials, their subsequent removal from the site of disposal, processing, reuse or recycling.

According to the Mesjasz-Lech [2], the most effective method of elimination of waste production and its negative environmental effects is economical waste evaluation. Sizes of flow concerning waste in cities are the main goal of reverse logistics of waste management. Conception of waste-free city needs activities of reverse logistics, because it is not possible to reduce communal waste without proper organisation of waste flows and infrastructure - function of the reverse logistics. Ecologically and economically effective waste flow organisation often encompasses greater region beyond city's borders.

The purpose of reverse logistics in the field of waste management is securing garbage collection, separation, transportation, storage, reprocessing (recycling) and waste recovery, which originates during production, wrapping and distribution of waste while we consider environmental impacts.

General drivers, which most influence waste production not only in Slovakia but on global scale, are mainly population growth and therefore urbanisation, growing concerns among public about the state of the environment, increasingly stringent national and transnational measures and regulations regarding waste and waste management.

Waste and its handling are among the most prominent problems in Slovakia. Country is not able to sufficiently handle it despite of growing pressure from EU through stricter requirements focused on these issues.

Linear economic model is still profound in Slovakia, which consists of entries in the form of mineral resources which are through design and production, transformed into possessions, then are supplied through distribution canals to particular users and used. Waste production is the last part of the chain as a result of consumption of manufactured possessions. This current economic model is based on high difficulty of entries (mineral resources), high rate of possession consumption and associated waste production.

The development of supply chain regulation methods in logistics, including the regulatory framework, has direct and indirect impact on the activities of logistics entities, creation of document flows and the implementation of logistics operations and functions [3].

In response on unsustainable consumer way of living and increasingly significant changes in the environment, EU adopted a package of measures in 2015, presenting recommendations and legislative proposals for the implementation of alternative economic model i.e. model of circular economy. Unlike the linear model, it is based on repeated material returning, components and products back into the production process. There is a constant transformation of production outputs into material inputs, while the main goal of circular economy is to reach the highest possible usability and product value of its parts and at the same time burden the environment as little as possible.

This package of measures was supplemented by specific objectives. In 2018, this goal was complemented especially in the area of recycling and waste prevention. In 2016, 193 countries committed to fight for a better future of our planet together by signing UN Agenda 2030, which comprises 17 goals of sustainable development [4].

In the Slovak Republic, the issue of waste management, the rights and obligations of legal entities and individuals in waste prevention and waste management, responsibility for breach of obligations in the waste management sector and the establishment of a recycling fund and hence retrospective logistics Act No. 223/2001 Coll. on waste in the last version are regulated and observed by the competences of state administration bodies and municipalities.

Act No. 223/2001 Coll. on Waste and on Amendments to Certain Acts defines waste as a belonging listed in the Annex to this Act which the holder discards, wishes to dispose or is in compliance with this Act or special regulations is obliged to discard it [5].

A new Circular Economy Action Plan for a Cleaner and More Competitive Europe was introduced by European Commission in 2020. In the document it is stated that:" despite efforts at both EU and national level, the amount of waste generated is not declining. 2.5 billion of tonnes of waste is generated across the EU from all economic activities, that means 5 tonnes of waste per capita. In addition, every person generates on average half a tonne of communal waste. The segregation of waste production from economic growth will require considerable effort throughout the value chain and in every household" [6]. The document further mentions that the implementation of a sustainable product policy will be a key to make a progress in waste prevention, increasing recycled content, promotion of safer and cleaner waste flows and ensuring high-quality recycling. In addition, as part of a wider set of waste prevention measures, the Commission will present waste reduction targets for preventing the waste production regarding regulation 2008/98/ES [7] for particular flows. All these measures are intended to contribute to the goal of significant reduction of the overall waste generation, namely, to halve the amount of residual (non-recycled) municipal waste by 2030.

Strong dependency on industry is one of Slovak specifics, which prevents its effort to alleviate the pressure on the environment. This is the main reason why Slovakia does not fulfil the requirements from action plans and other legislative EU documents. Slovakia as a whole is at this moment not able to adopt previously mentioned model of circular economy. It creates deviations from EU commitments and also other regional disproportions within the country.

Waste management is an activity aimed at the prevention and reduction of waste production, reduction of its environment hazards and waste disposal in accordance with this act. Waste disposal is collection of waste, waste shipment, waste recovery and waste defusing, including taking care of disposal sites.

Pursuant to § 19, par. 1 of this Act, the producer is obliged to collect created waste, separated by types and to protect them against devaluation, prevent them from being stolen or other undesirable effects and to use created waste as a source of secondary raw materials or energy especially in their own activities. These appointments define the basic obligation for the originators to carry out separate collection of waste [5].

The waste consists of unused materials and auxiliary substances in the manufacturing process, intermediates, malformations and surplus from manufacturing process, used packages and products. The originator of waste is everybody, whose activity waste originates in, or who manages modifications, mixing or other acts with waste, if the result is changing of character or composition. The waste holder is the producer of waste, individual or the legal entity by whom the waste is located. Waste defusing is a waste disposal, which does not harm the environment or threatens human health. Waste recoveries are acts which lead to physical, chemical or biological property changes of the waste. Waste separation is dividing waste by kind or segregation of waste components, which can be, after segregation, ranked as independent kinds of waste.

The purpose of waste management is:

- To prevent waste creation and to limit it mostly by the development of technologies that conserve natural resources; the production of products which, as well as the resulting products, minimize the amount of waste and reduce pollution of the environment as much as possible; the development of suitable methods of defusing dangerous substances contained in waste destined for defusing.
- Waste recovery by recycling, reusing or other processes that enable secondary raw materials to be recovered if waste prevention is not possible.
- To use waste as an energy source, if the material recovery is not possible.
- Eliminate waste in a manner that does not endanger human health and does not harm the environment.

Municipal waste is a waste created by households in the territory of municipality owned by individuals and waste of similar characteristics created during activities of legal persons or individuals-entrepreneurs and created by municipal activities during cleaning of public roads or open spaces, which are managed by municipality and during maintenance of public greenery, including parks and cemeteries [5].

Paper accounts for about 20% of the mass of municipal waste. Paper can be recycled very well (5-8 times) and can be subsequently composted. When recycling, the paper is pulverized into cellulose fibres and then processed again. In Slovakia we produce 850-thousand tonnes per year. The total annual production of the paper is 800 kg/SR inhabitant. Up to 50% of feedstock is a secondary raw material for paper production. Recycling 100 tonnes of paper saves about 1 hectare of a 100-year-old forest. The paper waste can also produce egg packages, kitchen towels, other packaging, toilet paper, cardboard and other paper products.

Paper packaging can be a part of global food waste solution, which represents up to 1.30 billion tonnes - one-third of food produced globally for our consumption - by minimizing waste and food damaging [8].

The primary function of packaging in all forms, plastic packaging, cans, glass and cardboards is to protect goods during transportation, storage and distribution. They prevent generation of waste resulting from breakage, spoilage and contamination and prolong the life of products. Secondary, but also an important purpose is to provide consumers with product information and to help identifying and distinguishing brands. Minimizing waste, especially food, is a major global challenge. Responsible recycling of waste and packaging paper reduces the amount of waste on landfills.

Glass constitutes to 12% of the total municipal waste mass. It is hygienic, ecologically significant and 100% recyclable. Glass containers can be reused 15 to 75 times. Melting results in losing its properties only insignificantly. According to the ecological ladder, re-use is more of a priority than recycling, because it is more environmentally friendly to use reusable packaging instead of putting it to recycling after use, so passing it back to the store. Glass is biologically inactive material - it does not decompose in nature (or decomposes for up to 4000 years). Sorted glass is processed directly in glassworks (no special processing plants are needed). For correct recycling, it is necessary to carefully sort glass by colour. When recycling glass is handled, it is best to break the glass into as little shards as possible and separate other components (labels or closures) from the glass products.

Plastics account for 7% of the total mass of municipal waste. Total annual production of plastics is 280 kg/SR inhabitant. Plastics are made from crude oil, which is a non-renewable natural resource. Plastics have a relatively small weight but a large volume. They are the worst recyclable material that has the most environmental burden. In nature, plastic bottle is decomposed in 50-80 years, but decomposition of PET bottles takes 400 years. Every minute, people in the world buy a million plastic bottles. One Slovak produces 8.4 kg of waste in the form of plastic bottles per year.

From the economy and ecology point of view, priority is given to recycling, but plastic cannot be recycled indefinitely because it loses its properties. Classified plastics produce various pulps or granules, which are subsequently used in the production of new products.

The packaging industry is the largest plastic producer in Europe. Up to 40% of plastic production in the European market ends in packaging, less in consumer goods and household, construction, automotive or electronics. Europeans dispose 25 million tonnes of plastic waste each year, of which only 30% is recycled.

Metals make up to 4% of the total amount of municipal waste - a much better package is e.g., aluminium, because metal or aluminium cans are a great commodity that can be recycled to infinity. Recycling aluminium cans consumes 95% less energy than their primary raw material production.

Biowaste accounts for 45% of the total amount of municipal waste or waste that goes to the composter, respectively. Recycling of biodegradable waste consists of compost, which results in the formation of a natural fertilizer. Usable in both large and small - in agriculture and in peoples' gardens.

Classed collection is free for citizens of the Slovak Republic. The citizen does not bear the cost of sorting in the local fee for municipal garbage and small construction waste. Financial responsibility for sorted collection is bore by the business entity whose products or packaging ends in communal waste.

By recycling from primary production, we save energy - for each raw material, it represents an energy saving of 97% for plastics, 95% for aluminium, 74% for steel, 70% for paper and 25% for glass.

Innovations focused on smart packaging for products that meet environmental, quality, safety or product identification standards within the logistics chain are currently gaining prominence. Effective operating on the market is not possible without these innovations in the packaging within the integrated innovation process on the market as well as without suitably organized logistics. In the future, this supports the development of products with smart packaging that can be considered as a smart system when it becomes part of a control or feedback mechanism in relation to its usage environment (Improved logistical handling and reduction of logistic costs, control of quality of packaging and contents, improved safety during packaging use, improvements in production of packaging and in reusing and recycling of packaging) [9].

2 Methodology

First feasible step in the research was detailed acquisition and study of basic theoretical knowledge from the literature for the creation of a model of reverse logistics, which has been applicable to Slovakia. These theoretical models are based on the assumption of a transdisciplinary approach, because limited understanding of reverse models could affect the creation and use of our model in Slovak conditions.

General theoretical models depicting various approaches to reverse logistics from different authors, which decribed Fleischmann [10] in his Quantitative Models for Reverse Logistics and Bloemhof-Ruwaard [11], with collective in their scientific publication Reverse logistics, have been used for the creation of reverse logistics model of waste collection. Authors implemented local specifics which took into account logistic processes and frameworks typical for waste procession in Slovakia (Figure 1).

Secondary material market represents in this model the place, where reverse flow (reverse logistics) happens; from where the waste in the form of material resources goes back into the production process. Their circulation thus radically minimizes the consumption of new material resources and energy needed for the production of new inputs and waste generation is minimized as well as the total costs associated with the production of goods. The most efficient use of resources within the technical and biological reverse cycle is the closure of material flows, ie. constant conversion of production outputs into inputs.

Waste management can be evaluated from the point of view of various indicators and aspects - economic, environmental or social, or qualitative. When creating the model, we dealt with economic factors and evaluation of economic efficiency. Within these evaluations, there are basic models, the authors Soukupová and Struk [12] also describe in their publications. The most commonly used methods for evaluating efficiency of public expenditure are Cost-minimization Analysis (CMA), Cost-effectiveness Analysis (CEA), Cost-utility Analysis (CUA) and Cost-benefit Analysis (CBA). We dealt specifically with Cost-effectiveness Analysis. This consisted of an assessment of two aspects: the effectiveness of expenditure per capita (E_1) and cost-effectiveness of producing one tonne of municipal waste (E_2).

Then the cost efficiency of given expenditure could be expressed as follows (1):

$$CEA = C / E \geq 0 \rightarrow min \quad (1)$$

where C is the environmental protection expenditure, E is the indicator of cost efficiency evaluation.

If CEA ≤ 1, the expenditure is efficient, if CEA > 1, the expenditure is inefficient. Because the criterion is minimizing, it needs to be transformed into maximizing one. Therefore for the construction of EKE criterion we will use the following formula (2):

$$E_E = 1 / CEA = E / C \geq 0 \quad (2)$$

where if EKE > 1, then the expenditure is efficient and EE → max [12].

The data that were analysed and compared in the article were used from the Eurostat database and from the study Analysis of Waste Management in the 8 largest cities in Slovakia [13]. It was an analysis and comparison of data dealing with the areas of municipal waste, expenditure per capita and expenditure on municipal waste production, using statistical methods.

3 Result and discussion

Main goal of reverse logistics is to gain the biggest value from elements, which form backflows, and it is also important to know how to deal with them.

Reverse model of waste collection and recycling in Slovakia is described on the Figure 1. Model was created by authors and comes from general models, which had been created by Fleichmann [10] and Bloemhof-Ruwaard et al. [11].

There are many options how to deal with returned goods. However, actual viability is limited by the intrinsic nature of the product (construction, degree of damage) and, of course, economic criteria- if demand exists for newly acquired materials, parts, whole products in the market. If this is not the case, the products must be stored in a landfill or be incinerated. The goods taken can be divided into categories according to the method of processing, namely [14]:

- Direct rescue – direct usage without any corrections (cleaning, repacking).
- Correction – broken products are repaired into functional condition.
- Recycling – product, or its part, is stripped-down on its basic materials, which are, after processing, used again. Substances, which would otherwise end as a waste, will be used as a raw material.
- Adaptation – requires a considerable amount of work. The product is discarded on parts that are checked, the damaged and worn are replaced by new.
- Upgrade – similar to correction, but with the difference that more work is needed, and the resulting product is of higher quality and value.
- Cannibalization – one or more parts of the product are used to repair another product.

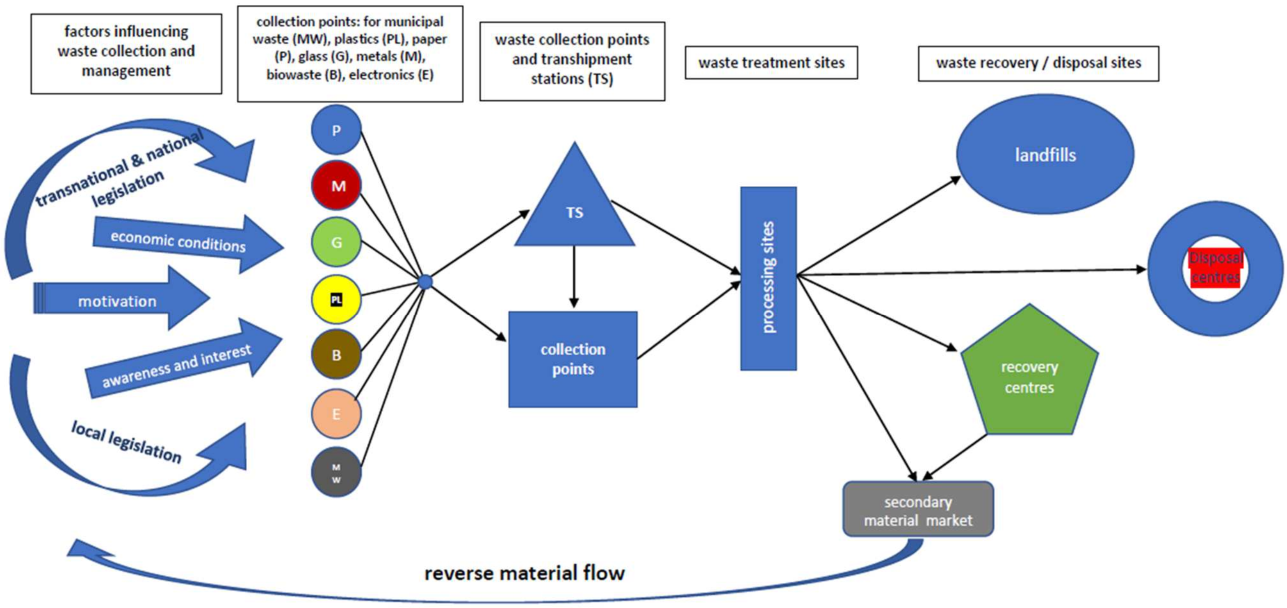

Figure 1 Reverse model of waste collection and recycling in Slovak Republic

Reversely aimed distributional channel represents collection of projects which provide reverse motion of waste and wrappings. Its existence and operation depend on multiple factors, such as country's legislation, economic conditions, motivation, awareness and interest in the solution of waste collection.

Reverse logistics nowadays represents a remarkable part of logistics processes of the company. Under Slovak conditions, it is possible to find ways of its application in an indirect form, especially in the form of waste management.

3.1 Case study: Cost efficiency analysis in the selected Slovak municipalities

Municipalities play a significant and a very important role in waste management. They set their goals in waste management, try to meet them, while spending a substantial part of their budgets on them. For local governments, the most important aspect is considered to be the economic aspect, namely the efficiency of public funds spent on waste management. Therefore, we focused on the Cost-effectiveness Analysis (CEA) in selected municipalities, specifically in the eight largest Slovak cities: Bratislava (BA), Košice (KE), Prešov (PO), Nitra (NR), Banská Bystrica (BB), Žilina (ZA), Trnava (TT) and Trenčín (TN). These municipalities were also chosen because of the availability and completeness of relatively up-to-date data (2019) related to their waste management. The data were drawn from the study Analysis of Waste Management in the 8 largest cities in Slovakia [12].

In 2019, these 8 local governments produced a total of 559,268 tons of municipal waste, which is approximately one quarter of all waste produced in the same year in Slovakia. The average level of waste separation in these cities was almost 41%. The individual data for the above-mentioned eighth municipalities are given in the table below (Table 1).

Table 1 Information about selected municipalities and their waste management

2019	BB	BA	KE	NR	PO	TN	TT	ZA
Population	76147	437725	238757	78353	88464	54696	63751	82867
amount of municipal waste (t)	45070.5	213047.6	97403.3	47382.6	41586.4	28562.8	39717.6	46497.7
amount of MW per inhabitant (t)	0.59	0.49	0.41	0.60	0.47	0.52	0.58	0.56
separation rate	53.37%	31.30%	29.33%	42.00%	39.06%	40.27%	46.55%	43.53%
mixed waste	39%	53%	50%	50%	54%	48%	43%	43%
costs in waste management (€)	3724184	28723806.6	12667724	3869321.7	4791941.2	2305890	3544655	3197723

Source: authors' computation

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According to the above-mentioned methodology, we calculated the Cost-effectiveness Analysis (CEA). This consisted of an assessment of two aspects: the effectiveness of expenditure per capita (E_1) and cost-effectiveness of producing one tonne of municipal waste (E_2). The results are shown in the tables below (Table 2 and Table 3).

Table 2 Expenditure per capita related to municipal waste (€)

Municipality	CEAj
Banská Bystrica	48.9
Bratislava	65.6
Košice	53.1
Nitra	49.4
Prešov	54.2
Trenčín	42.2
Trnava	55.6
Žilina	38.6

Source: authors' computation

The average expenditure per capita on municipal waste in the eight municipalities was 50.9€. Expenditures per capita consider the minimization criterion, i.e., the lower the expenditures, the more efficiently they are spent in waste management. The highest expenditures are in the capital Bratislava (65.6€) and the lowest in the city Žilina (38.6€).

Table 3 Expenditure on the production of one tonne of municipal waste (€)

Municipality	CEAj
Banská Bystrica	82.6
Bratislava	134.8
Košice	130.1
Nitra	81.7
Prešov	115.2
Trenčín	80.7
Trnava	89.2
Žilina	68.8

Source: authors' computation

The average expenditure per tonne of municipal waste in the eight municipalities was € 97.9. Expenditures again consider the minimization criterion, i.e., the lower the expenditures, the more efficiently they are spent in waste management, with the highest expenditures in the capital Bratislava (€ 134.8) and the lowest in the city Žilina (€ 68.8). The differences between individual expenditures per capita and expenditures per tonne of municipal waste produced are mainly due to the sale of secondary raw materials, subsidies for certain types of waste and other fees associated with waste management (e.g., legal entities fees).

In order to transform the minimization criteria into maximization, according to the above-mentioned methodology, we calculate the effect of using the effectiveness of expenditure per capita (E_{e1}) and the effect of using the efficiency of expenditure per one tonne of waste produced (E_{e2}). More in Table 4 and Table 5.

Table 4 The effect of using the efficiency of expenditure per capita

Municipality	E_{e1}
Banská Bystrica	0,0204
Bratislava	0,0152
Košice	0,0188
Nitra	0,0202
Prešov	0,0185
Trenčín	0,0237
Trnava	0,0180
Žilina	0,0259

Source: authors' computation

Table 5 The effect of using the efficiency of expenditure on expenditure per tonne of waste produced

Municipality	E_{e2}
Banská Bystrica	0,0121
Bratislava	0,0074
Košice	0,0077
Nitra	0,0122
Prešov	0,0087
Trenčín	0,0124
Trnava	0,0112
Žilina	0,0145

Source: authors' computation

The above calculations show that the highest effect of the efficiency of expenditures used per capita, even per tonne of waste produced is achieved in the city of Žilina and, conversely, the lowest is in the capital of the Slovak Republic - Bratislava.

3.2 Reverse logistics system

Some studies [15] show, that the total cost of the reverse logistics system is largely determined by the cost of transport activities required to collect packaged food waste from the retail stores and ship it to the distribution centres for storage; conversely, the transport cost from the distribution centres to the main facilities contributes to the total cost of the system to a very limited extent.

Recycling is an extensive re-entry of solid, liquid, gaseous waste into the circulation and the re-use of waste energy and heat. Recycling of industrial waste is a backflow into original manufacturing process and gain of secondary raw materials for manufacturing new, other products. Recycling of consumer goods mean backflow into original manufacturing sector and gaining raw materials for new products. Reverse usage of packages is a reverse move of wrapping packages, i.e., recycling-manufacturing technology.

Recycling is repeated use and product evaluation or a part of the product in the form of material and energy circulation, which: saves primary raw material sources; lowers power consumption by using secondary raw materials; reduces amount of waste, which is necessary to defuse, respectively eliminate; lowers environmental burden.

We can distinguish between several possible scenarios for **waste treatment:** reuse of substances (recycling), thermal treatment and landfill.

In the re-evaluation of the waste, the waste is taken over and transported to a special sorting and processing facility where the material balance of the fractions it consists of is taken into account, taking into account the possibilities of further use as a secondary raw material for the preparation of a new product, respectively their use as auxiliaries.

For thermal treatment, the waste is transported to a special thermal treatment plant (incineration plant) where it is directly incinerated and, most of the time, thermal or electrical energy is generated. This scenario is suitable for residual plastic films and paper. Waste incineration plant means any stationary or mobile technical unit and equipment designed for the thermal treatment of waste with or without the utilization of the combustion heat is generated. It includes the process of combustion by oxidation of waste as well as other heat treatment processes such as pyrolytic, gasification or plasma processes, if the substances resulting from the treatment are subsequently incinerated.

Waste landfilling is characterized by high environmental burden, in which case waste is transferred to a landfill and dumped there without further processing or use. This way of waste destruction is the most unecological one and there is a risk of possible soil or water contamination, possibly air pollution by harmful substances.

The specific chapter are dangerous substances, it is very important when handling them to familiarize the workers with the valid legal regulations in order to ensure proper handling, transportation, storage and disposal in compliance with the safety regulations. By "hazardous waste" we mean any solid or liquid waste as defined in Article 1 par. 4 of Council Directive 91/689 / EEC on hazardous waste.

When we focus on processes of reverse logistics from the point of economic expenses, it is possible to divide these expenses into expenses for recycling, collection, separation, transportation, storage and further waste treatment. Expenses for waste elimination in the form of landfill or waste incineration cause environmental burden, which are hardly quantifiable. The state is therefore trying to regulate by means of orders, prohibitions, taxes, subsidies and other economic instruments. In line with the Slovak Waste Management Program, industrial enterprises should preferably focus on the recovery before disposal, thus gaining a competitive advantage for the future.

Figure 2 shows the share of different economic activities and households in a total waste generation in 2016. In the EU-28 in 2016, 36.4% of the total waste was generated in construction, followed by mining and quarrying (25.3%), manufacturing (10.3%), waste and water services (10.0%) and households (8.5%). The remaining 9.5% generated waste was from other economic activities, mainly services (4.6%) and energy (3.1%) [16].

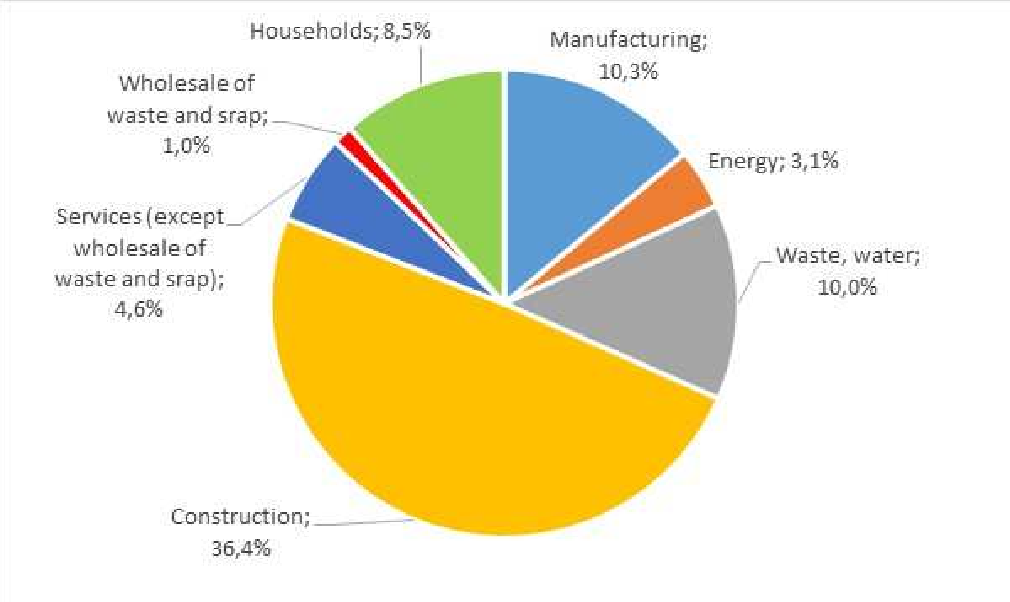

Figure 2 Waste generation by economic activities and households, EU-28, 2016 (%) [16]

The goal of EU waste treatment policies is to reduce the impact of waste on the environment and health and to make EU resources used more efficiently. Proper waste management is a key element in ensuring the efficient use of resources and the sustainable growth of European economies [16].

Each Slovak produces on an average of 321 kg of waste per year. Of this, only about 20 kg is recycled. Every European on average accounts for 475 kg of municipal waste. Of this, about 133 kg is recycled (Figure 3).

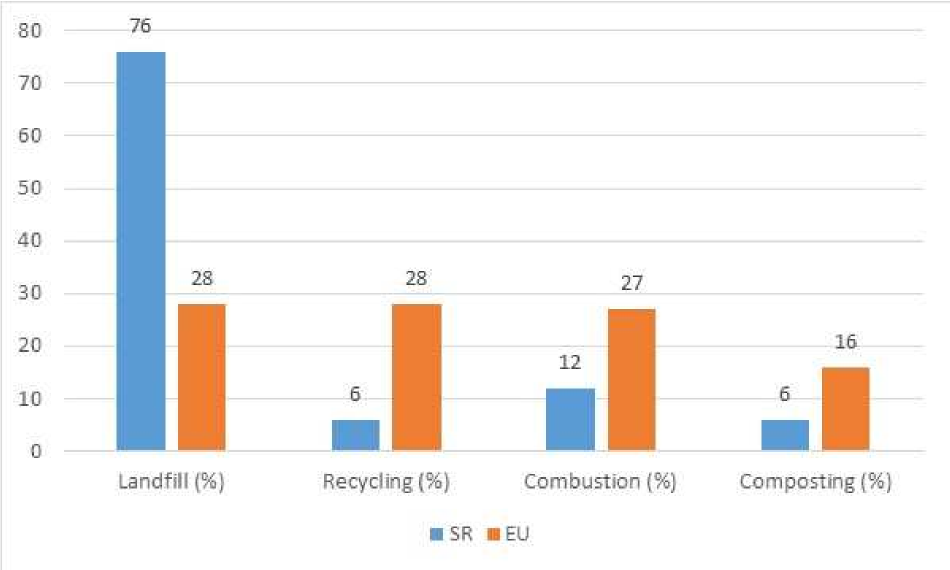

Figure 3 Comparison of waste management with EU countries [17]

Priority goals for waste politics in EU:

- To reduce the amount of created waste.
- To maximize recycling and reusing.
- To limit combustion- burn only non-recyclable materials.
- To gradually remove landfilling of waste, which can be recycled and evaluated.
- To ensure full achievement of waste policy in all EU Member States [16].

Supporting Member states in waste management requires additional efforts. There is a threat that half of them will not be able to fulfil the goal for the year 2020, which is to recycle 50% of communal waste (including Slovakia, which recycled 39% of it in 2019). In order to push political reforms, Commission will organise exchanges regarding circular economy and waste, will intensify cooperation with Member states, regions and cities to make the best use of EU funds. According to a survey conducted by Sensoneo in 2019 [18], Slovakia is among the worst waste managers among OECD countries.

The landfill site is a waste disposal site where waste is permanently deposited on the surface of earth or in the ground. The waste disposal site is also considered to be the place where the waste producer carries out the disposal of their waste at the site of production (internal landfill), as well as the place that was used longer than one year and is used for the temporary storage of the waste. Waste landfill shall not be considered as a facility where waste is deposited for the purpose of its preparation prior to its further transport to a location where it is treated, reclaimed or disposed of, and the time of its storage prior to its recovery or modification does not normally exceed three years or does not exceed one year [5].

Advantages of a landfill: availability, low operating costs and use of methane (only on some landfills). Disadvantages of landfilling include space-related challenges, hazardous landfill gas (forming methane that heats the atmosphere) and the risk of contamination of groundwater. Methane is generated on the landfill and its production is one of the most serious impacts of landfills on the environment. The process of fermentation takes place in communal waste i.e., the biodegradation. It releases landfill gas - methane and carbon dioxide. Some studies say methane has a 25 to 72-fold greater impact than CO_2 on global warming. Up to 80-90% of methane is released in the first 10 days, and then it decays in the landfill for the next 30 years. That is why the EU is pushing for a restriction on landfills. An effective solution to this problem in combating waste is waste incineration. In Slovakia, we currently have only two municipal waste incinerators (Bratislava, Košice). For comparison - in the Czech Republic, they have 4 such incinerators, in Austria 12, in Germany 164. Of course, if something burns, it produces hazardous waste, but the combustion of waste is subject to the strictest emission control by all energy producers. Flue gas cleaning is the most expensive of all costs.

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At present, we have 125 legal waste dumps in Slovakia. There are 2500 registered illegal landfills, unofficially 7000. While some countries are advancing in the direction of waste disposal and managed to reduce or totally eliminate landfill waste, Slovakia has the biggest amount of waste, which ends in the landfills (Figure 4) and only a small part is recovered. Goal, which we want to achieve, is exactly the opposite.

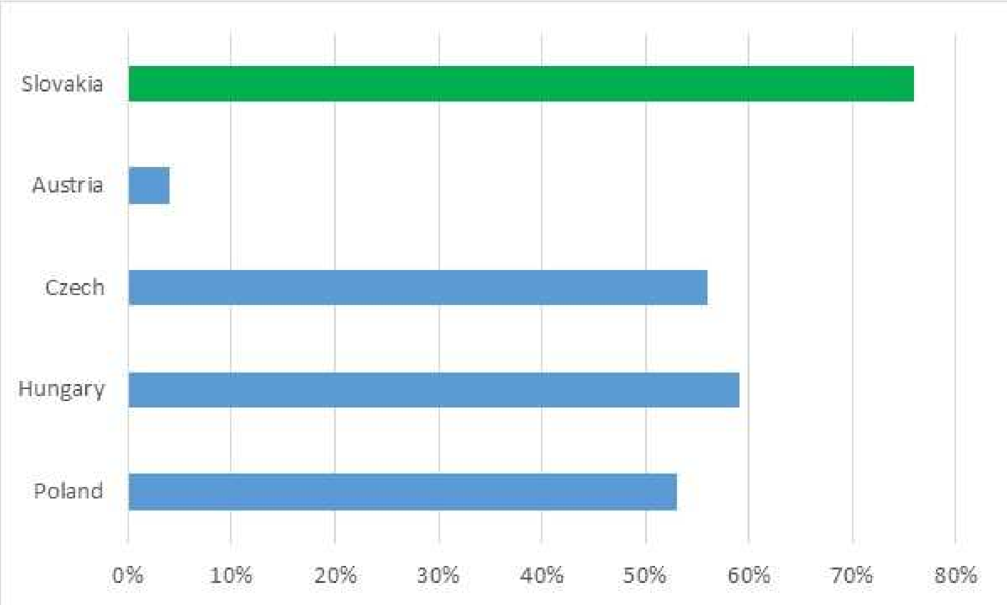

Figure 4 Comparison of municipal waste in landfills [19]

Benefits of combustion: waste reduction, reduces landfilling, energy production that melts into electricity and heat. Among the disadvantages of patio incineration are higher costs, little incinerations and mistrust of citizens.

Of course, it is way of enlightening people, to become more conscious and to conscientiously separate waste. Waste separating, respectively it is further usage of secondary raw materials in production process affects the final product cost- producers have lower expenses, what in the end lowers final costs for consumers.

Waste management is a very wide area for business. In the current state, most towns and villages in Slovakia are also collecting and exporting through standard 110, 120, 240 and 1100 litres collecting containers, which provide space for the collection of mixed, especially municipal waste, and at the same time offer the opportunity to carry out sorted waste collection. However, this situation is inadequate in the light of an evolving living standard, particularly in terms of increasing waste quantities, due to the development of living standards and packaging technology, as the amount of waste is increased especially in municipal waste, mainly in terms of its volume. This creates pressure to increase the number of waste containers, resulting in increased space requirements and the limitation of other necessary functions in a massive housing such as static transport, greenery, and the like.

Global population growth and urbanization increase the demand for additional waste disposal systems, thereby stimulating the growth of the waste market. This developmental impact of the company requires an innovative solution in waste management. The solution to this problem is, for example, the introduction of new systems for a semi-submersible waste collection system using semi-submersible containers. It is a substantially larger container that is embedded in the ground (containers need just a small area, as 60% of the container body is underground). This system saves up to 80% of the area in the collection points and holds up to 6 containers of standard 1100 litres containers in one container. These types of waste containers are most often installed abroad in public places such as shopping malls, airports, office complexes, metro stations and other projects. A very important added function has recently been the implementation of IoT technology in containers in the form of scanners and sensors. Using IoT and data integration, information about waste, its quantity, current condition of containers and their location is collected, and optimal routes for waste collection are selected. Therefore, there is a further reduction in labour costs, fuel, respectively. vehicles.

Main difference, which these semi-submersible waste containers in comparison with the typical ground waste collection have, is an advantage of the location in dedicated places. Therefore, they are a part of permanent infrastructure network with precise location of waste collection, instead of a service dedicated just to particular house/houses using common waste receptacles and standard collection schemes. Planning of this container network can bring significant benefits in logistics of waste management and environmental protection.

For example, in older urban areas, conventional door-to-door waste collection is often challenging due to differences in housing development, topography, climatic conditions, limited space for waste bins and means of transport, as well as frequent accidents at work among waste collection staff [20].

It is expected that the capacity of semi-submersible waste containers market will have reached 1050,1 million $ in 2027 from 796,7 million $ in 2019 [21]. These factors will be reflected in the growth of construction activities around the world, increasing demand on space and increased efficiency of space utilization, order and long emptying intervals, which reduce traffic congestion in cities. The further growth of this segment is also indicated by the increasingly stringent measures of the standard concerning the collection, sorting and waste disposal in European regions.

Benefits of semi-submersible containers can be divided into saving of space, odour reduction, improving of work safety, healthy and safe working environment for the cleaning staff, waterproof and durable construction, only a few moving and breakable parts, adjustable appearance.

Benefits of waste separation can be divided into economic **benefits** (**f**ewer emptying pick-ups, reduced fuel consumption, less emptying personnel), environmental benefits (quiet emptying, aesthetical attractivity encourages cleanliness, reduced CO_2 emissions) and social benefits [22].

Weaknesses of semi-submersible containers:

- The need for an entry building investment.
- Changing the export system (the need to secure a suitable harvesting technique).
- The need to change business and logistics relationships.
- The advantage of a system for concentrated waste production sites.

The 7th Environment Action Programme (EAP) will be guiding European environment policy until 2020: "In 2050, we live well, within the planet's ecological limits. Our prosperity and healthy environment stem from an innovative, circular economy where nothing is wasted and where natural resources are managed sustainably, and biodiversity is protected, valued and restored in ways that enhance our society's resilience. Our low-carbon growth has long been decoupled from resource use, setting the pace for a safe and sustainable global society."

It identifies three key objectives [22] to protect, conserve and enhance the Union's natural capital; to turn the Union into a resource-efficient, green, and competitive low-carbon economy; to safeguard the Union's citizens from environment-related pressures and risks to health and wellbeing.

Slovakia is one of the countries within the European Union characterized by the low eco-innovation index. GDP belongs to key factors enabling effective support for eco-innovation. The failure of global logistics during these days, where the pandemic negatively affected economic growth, replaces local logistics - which is also a positive factor for eco-innovation [23]. Slovakia could use this period to start the positive changes that will have a significant economic, social and environmental impact.

Many professionals and specialists make comment on and assess the system of circular economy as a new phenomenon. According to them, its priority is saving and effective use of restricted natural sources, streamlining of goods production at high effectiveness and lower consumption of sources and low (or even zero) production of emissions. It involves prevention and lowering of waste production and subsequently the sources of polluting materials up to recycling when the sources return to the economic cycle, which has still more urgent practical importance [24].

4 Conclusions

Although reverse logistics as a separate part of the logistics chain has only begun to emerge in recent years, it is an important part of business processes. Under European understanding, its application serves as a tool to mitigate the adverse environmental impacts of the economy and the health of the population. Proper waste management is a key element in ensuring the efficient use of resources and the sustainable growth of European economies. The priority objectives for waste policy in the EU include reducing the amount of waste generated, maximizing recycling and gradually eliminating landfilling.

Main purpose of waste management is to prevent waste production and reduce it mainly by developing technologies for protection of natural resources, production of goods which minimise amounts of waste and reduce environmental pollution as much as possible, development of suitable methods for disposal of hazardous substances contained in waste intended for disposal, waste recovery by recycling, by reusing or other processes, to use waste as an energy source, to eliminate waste in a way that does not endanger human health and does not harm the environment.

Nowadays, and not only in Slovakia, but waste production is also affected by population growth connected with urbanisation. State of the environment is highly topical issue. Increasingly stringent national and transnational measures and regulations regarding waste and waste management are coming to the fore.

The originator of waste is everybody, whose activity waste originates, or who manages modifications, mixing or other acts with waste, if the result is changing of character or composition.

One of the main problems of Slovakia remains low performance regarding waste management, low recycling rate and strong dependency on landfilling. Among OECD countries Slovakia belongs to the 10 worst waste managers. In 2019, Slovak residents produced 2.3 million tonnes of communal waste. Per capita, it is approximately 435 kilograms. Slovakia is currently not able to fulfil the goals, which determined regarding increased rate of waste recycling to 50% in 2020. Currently, this rate is at 39%. Therefore, change in the waste management performance is inevitable. It would be largely dependent on the push of new waste legislation and other fiscal stimuluses. Another significant, not only ecological problem in Slovakia is landfilling. About 50% of waste produced ends on landfills.

At present, we have 125 legal waste dumps in Slovakia. There are 2500 registered illegal landfills, unofficially 7000. Current course shows that Slovakia unfortunately will not get rid of mass landfilling. Even though in March 2019 there was a law change on landfilling fees, which set landfilling prices and defined also it is gradual growth, in comparison with neighbouring countries these fees are still very low. This is also one of the reasons why, in addition to our waste, garbage from nine other countries is imported to Slovakia and also ends up here. We consider it very important that all that responsible will apart from waste management also pay close attention to waste prevention.

Waste separating, respectively it is further usage of secondary raw materials in production process affects the final product cost- producers have lower expenses, what in the end lowers final costs for consumers. Innovations focused on smart packaging for products that meet environmental, quality, safety or product identification standards within the logistics chain are currently gaining prominence. Effective operating on the market is not possible without these innovations in the packaging within the integrated innovation process on the market as well as without suitably organized logistics.

Input factors are important when creating a reverse model, we pointed out in the article the cost-effectiveness with regard to the use of municipal waste. We applied the cost-effectiveness method to cities in the Slovak Republic and then compared the results.

While creating reverse model input factors are important, as we pointed out in the article focused on cost effectiveness considering the use of communal waste. Method of cost effectiveness had been applied on Slovak cities and then the results were compared.

In order to start the discussion about circular economy in Slovakia, economic and legislative motivation for prioritising eco-design, prevention of waste production, its separation and recycling with high added value of output products is essential, both at the citizen level and at the level of companies or institutions.

Acknowledgement
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SOLVING THE BOTTLENECK PROBLEM IN A WAREHOUSE USING SIMULATIONS

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Keywords: bottleneck, workforce allocation, simulation, ExtendSim
***Abstract*:** The uneven workload distribution and working time utilisation create a bottleneck, leading to inefficient utilisation of capacity and increased costs. A bottleneck is a limiting and risk factor for any business entity. In the case of a distribution warehouse, the bottleneck limits its ability to meet the requirements for sending an order within the required time limit. Delays at any phase of a distribution process may result in non-compliance with customer requirements. In solving capacity problems and bottlenecks elimination, computer simulations and optimisation are often used. The article presents a basic simulation analysis of workload distribution and work times, useful for logistics companies, thus for the area of human and financial resources. In the article, the use of simulations in the ExtendSim9 program to eliminate the bottleneck is discussed. The bottleneck is solved by experiments on a simulation model when optimal workers assignment to individual workplaces of the warehouse is sought. The two final proposals for workers allocation, with the current and increased number of workers, are compared in workforce utilisation and system stability. The simulation method allows verification of the proposals' impacts in advance and practically with no financial costs.

1 Introduction

The efficiency of activities in a distribution warehouse depends on several factors. The organisation of storage space, the layout of shelves and management of workforce and workflow are among the most important. The process of ensuring the shipment, from receiving the order, determining its priority, packaging, and picking, must be managed within the required time limit. Delays at any stage may result in non-compliance with the delivery deadline. The issue of warehouse optimisation is solved in science papers from different points of view. Warehouse layout and the picking performance were solved in many of them. For instance, Amorim-Lopes et al. [1] presented a three-step methodology to analyse and experiment with layout and storage assignment policies to improve the picking performance.

Similarly, [2] studied the optimal layout design for block stacking. Minimising the travel distance of a picking tour is often considered an imperative factor in improving warehouse operation efficiency. The paper by [3] concentrated on the performance of the genetic algorithm method and its comparison to other routing strategies such as heuristics, the experienced warehouse picker and the brute-force algorithm under given assumptions. Possibilities of optimisation the stocks were pointed out in [4]. Mirčetić et al. [5] focused on the problem of forklifts engagement in warehouse loading operations. The methodology for carton set optimisation in e-commerce warehouses was proposed and evaluated by [6]. Their carton set optimisation approach can improve the shipping cost and carton utilisation, and so considerably improve the carbon footprint of the operations. An increased number of e-commerce companies implement the unmanned smart warehouses. In order to reduce the demand response time in this smart warehouse, a novel picking strategy was designed by [7] to firstly split the orders, and then assign the partial orders to different pickers. The paper by [8] discussed the optimisation of warehouse management in the assembly and distribution company, which was made using particular methods of multi-criteria evaluation of variants. Using the data envelopment analysis, the performance of a logistic company with twelve warehouses was evaluated in [9].

Order picking is one of the most challenging activities in terms of time, labour, and cost for most warehouses [10]. Mainly e-commerce warehouses face ever smaller orders that must be delivered ever faster, often within 24 hours. That puts pressure on the order picking process as the orders pickers' workload becomes higher and higher and leads to congestion in the warehouse [11]. Firms need to focus on many factors to achieve their goals such minimising costs, profit maximisation and increasing system efficiency. One of the significant factors impacting the productivity of warehouses is workforce. Besides the correct selection of employees, their motivation and qualifications, also correct assignment of employees to workplaces and a fair distribution of work among the employees is important. Personnel scheduling has a significant influence not only on the warehouse productivity but also on the development of employee competencies [12]. Ernst et al. [13] considered an employee scheduling problem arising in service industries with flexible employee availability and flexible demand. In the literature review [14], new trends and approaches were presented for the personnel scheduling problems. Similarly, authors of [15] reviewed rostering problems in specific application areas and the models and algorithms that had been reported in the literature for their solution.

It is important to state that many software tools are developed for staff scheduling, often based on mathematical models using efficient optimal or heuristic algorithms. Masoud [16] developed a simulation-based optimisation framework for labour management to optimise labour allocation. Andersson [17] presented a simulation-optimisation system for personnel scheduling in which the multi-objective evolutionary algorithm NSGA-II had been implemented. Among the software tools, ExtendSim is often used for simulation and optimisation [18]. In the literature, there are presented many researches and real-word studies about ExtendSim application. For example, using ExtendSim to optimise the delivery process is presented in [19], to streamline production logistics in [20], to optimise wastes flow in [21] and assess the meat processing and cutting production in [22]. Also, optimising the command and control process based on ExtendSim was researched by [23] and machinery allocation in the container terminal by [24]. In the nonindustrial area, as an example can be mention [25], which used CPLEX and ExtendSim to solve the stochastic optimisation model for Emergency Department.

The aim of the paper is optimisation of the workforce allocation in the warehouse. Simulation and optimisation are performed by software tool ExtendSim9. The simulations will verify alternatives for assigning workers to the picking and packing workplace to eliminate the existing bottleneck and uneven workload.

2 Materials and Methods

2.1 Case study description

The distribution warehouse of the internet storage with nutritional supplements is operated as an e-shop without stone shops. Customers order goods through the company's website. The store delivers the goods within 24 hours, if the order was placed within the specified time limit. If later, then the shipment is delivered within 2 days. Approximately 80% of orders go to export. The average number of orders received is 2 600 to 2 800 per day. Table 1 shows the time and number of received orders from 15.01.2020, when 2 673 orders were received. Picking starts at 6:00 and lasts until 18:00. From the overview in Table1, it is evident that most orders come for picking at 6:00, but this does not mean that customers sent their order at this time. All orders that arrive after the 24-hour delivery time limit are carried over to the next day and packed in the morning at the beginning of the shift.

Table 1 Time and number of orders received for individual transport companies

	Transport company /Number of orders						
Time	Cargus	GLS Hr	Zásielkovňa	PPL	GLS HU	Post	DHL
6:00	236	42	83	73	116	95	76
7:00	7	6	10	8	11	7	6
8:00	37	10	18	14	18	14	13
9:00	58	17	26	21	34	19	19
10:00	67	22	31	37	38	30	27
11:00	73	27	43	43	44	39	34
12:00	87	32	46	46	57	37	41
13:00	17	6	54	55	63	51	56
14:00					69	54	51
15:00					26	39	62
16:00					12	21	20
17:00						6	16

Picking up goods in the warehouse is done manually using human force. Orders are packed according to priority. The highest priority is given to orders that belong to the transport company that leaves the warehouse first. The company uses services of seven transport companies for delivery. Transport companies and departure times for individual transport companies are listed in Table 2.

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Table 2 Departure times for individual transport companies

Transport company	Deadline for packing all packages
Cargus	13:50
GLS HR	13:50
Zásielkovňa	14:20
PPL	14:50
GLS HU	17:20
Post	17:50
DHL	18:00

2.2 *Problem definition and method of solution*

Observations have shown that picking and packing workers are unevenly distributed, causing significant downtime. The high number of pickers and the low number of packaging workers will cause them not to catch up to pack orders, and the conveyor will become clogged. Therefore, the pickers will not send another order and will have to wait until the space on the conveyor becomes free. On the contrary, the high number of people at the packaging lines and the low number of picker will cause few crates to come on the conveyor and thus workers will have to wait for the order, which causes considerable downtime, which threatens delivery to the customer within 24 hours of ordering.

The solution of this problem is sought by using a simulation model in the ExtenSim9 program, which simulates the arrival of an order for picking, its picking and the arrival to packing lines. Alternatives to the allocation of workers to the picking and packing workplace to eliminate the existing bottleneck and uneven workload will be experimentally verified by simulations.

2.3 *Creating a simulation model in ExtendSim9*

The simulation model is created based on data from the analysis of the order picking process. The basis for the simulation model is a scheme of the simulation model showing chronologically the sequence of activities. The intervals and the number of incoming orders per day were determined by observation and measurement. Subsequently, the time of picking up of one order and the time required for its packaging were measured. The scheme of the simulation model is shown in Figure 1., other input data related to the process of picking orders are in Table3.

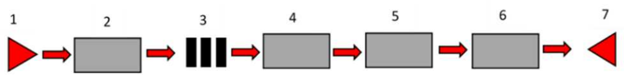

Figure 1 Scheme of simulation model
1. received orders, 2. priority assignment to orders, 3. row, 4. product pickup, 5. product transfer, 6. packing, 7. dispatch

Table 3 Input data for the simulation model

Workplace	Time of process (min.)			Conveyor capacity (crates)	Emploee
	Min.	Max.	Likelist		
Picking	2.5	5.5	4.0		28
Transport	0.6			40	
Packing	2.5	4.0	3.3		

Based on the scheme, a simulation model is created in the environment of the simulation program ExtendSim9 (Figure 2). Parameters for the simulation are entered based on measured values. The simulation time is 720 minutes and represents a 12-hour work shift. The model is shown in Figure 2, and the individual blocks of the model are marked with a number in the figure, while the description of their function is as follows:

1. "Create" blocks, each of which represents the transport company to which the orders belong. The blocks generate orders that arrive to the system at time intervals specified in Table 1.
2. The "Set" blocks assign priority to each order. Prioritisation is done in descending order.
3. The "Select Item In" block is used to combine input request streams into one stream.
4. The "Queue" block represents the stacker at Picking, where orders waiting to be processed are accumulated. The "Queue" block setting is by priority system.
5. The first block "Activity" in the model represents Picking, where the products are picked up from the warehouse according to the order. The time to pick up one order here is at least 2.5 minutes, at most 5.5 minutes and most often 4 minutes.
6. The block "transport" represents the movement of the order in the crate on the conveyor, where the movement time is 0.6 minutes, the capacity of the conveyor is 40 crates.
7. The second block "Activity" represents the packaging, where the products picked up from the "Picking" on the conveyor come. The time settings are as follows: at least 2.5 minutes, at most 4 minutes and most often 3.3 minutes.
8. The "Select Item Out" block is used to divide one input request stream into any number of output streams.
9. Requests leave the system via the "Exit" blocks. The simulation model contains seven such blocks representing transport companies.
10. The last block "Plotter Discrete Event" plots graphs of the simulation process from the input values.

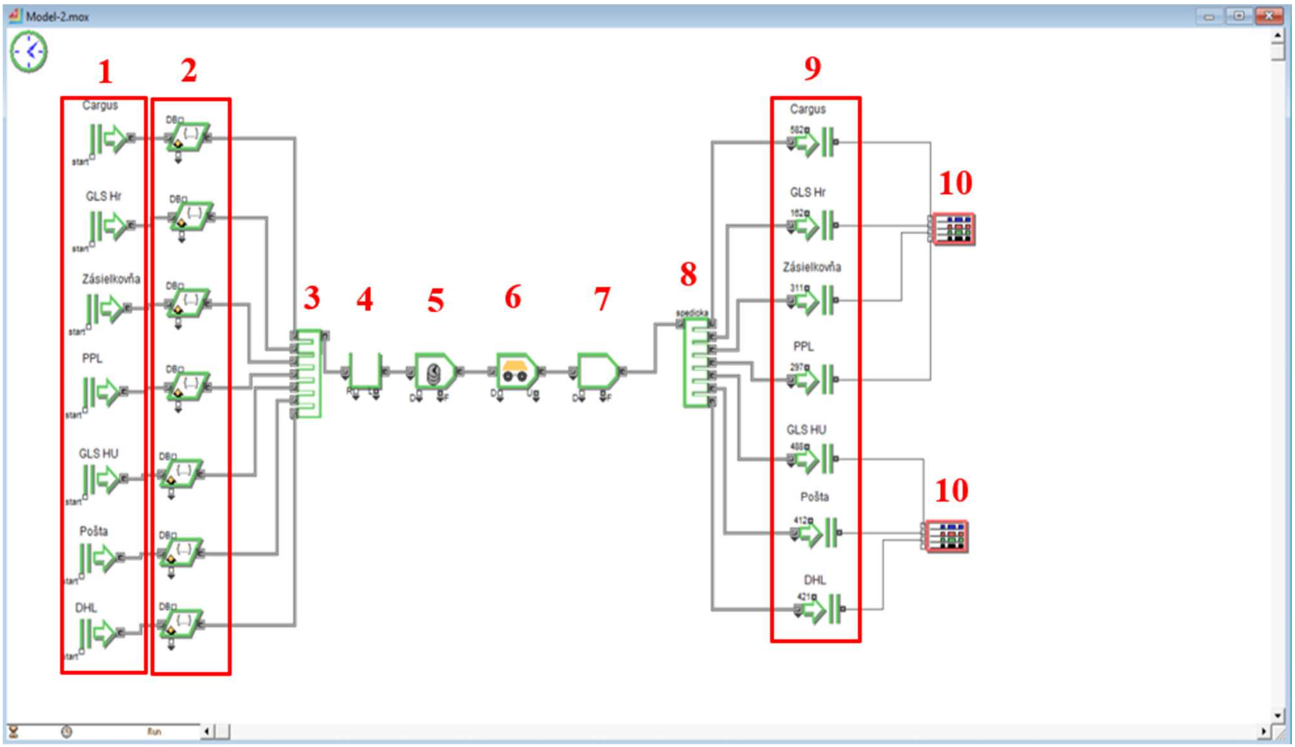

Figure 2 Simulation model in ExtendSim9 program

3 Results and discussion

The simulation model is applied to experimentally verify the operation of the warehouse and optimise the schedule of activities for the workforce. Two proposals for the organisation of work are verified experimentally. Proposal number 1 considers the current number of employees and experimentally redistributes the employees at both workplaces in order to find the optimal distribution of the workforce. Proposal number 2 envisages an increased number of workers to reduce the system's high workload and tension. Also, in proposal number 2, the schedules of the increased number of employees are experimentally verified in order to achieve an optimal workload utilisation of approximately 80%. This would reduce the risk of bottlenecks and failure of processes.

3.1 Proposal No. 1 with the available number of employees

The first proposal simulates a system with an available number of employees, representing 28 employees per one shift. The model is first necessary to enter the measured values for the individual "Activity" blocks. In the first "Activity" block, which represents Picking, we set the shortest time to 2.5 minutes, the longest time to 5.5 minutes and the most likely time to 4 minutes. The second "Activity" block represents the packaging lines, where the time settings are as follows: shortest: 2.5 minutes, longest: 4 minutes and the most likely time to 3.3 minutes. In the "Transport" block, a value of 0.6 minutes for the move time is entered, representing the time required to move the crate from Picking to the packing line. Finally, it is necessary to enter the number of employees in the individual "Activity" blocks. The utilisation of "Activity" blocks is shown in Figure 3.

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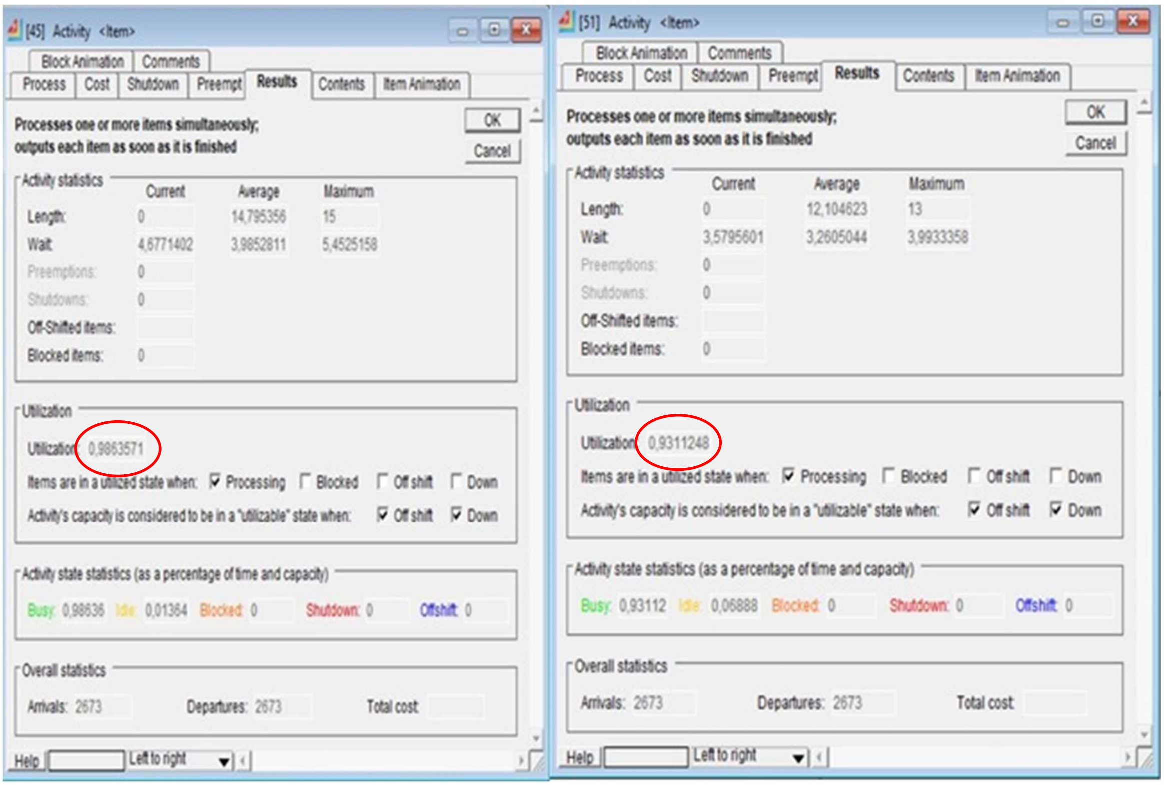

Figure 3 Use of activity-Picking and packing blocks

Figure 4 and Figure 5 display the course of the simulation in proposal 1. In the figures, order packing times for individual transport companies are expressed by colour curves. The vertical axis expresses the number of processed orders. The graphs show that all orders received were packaged but just before the time limit.

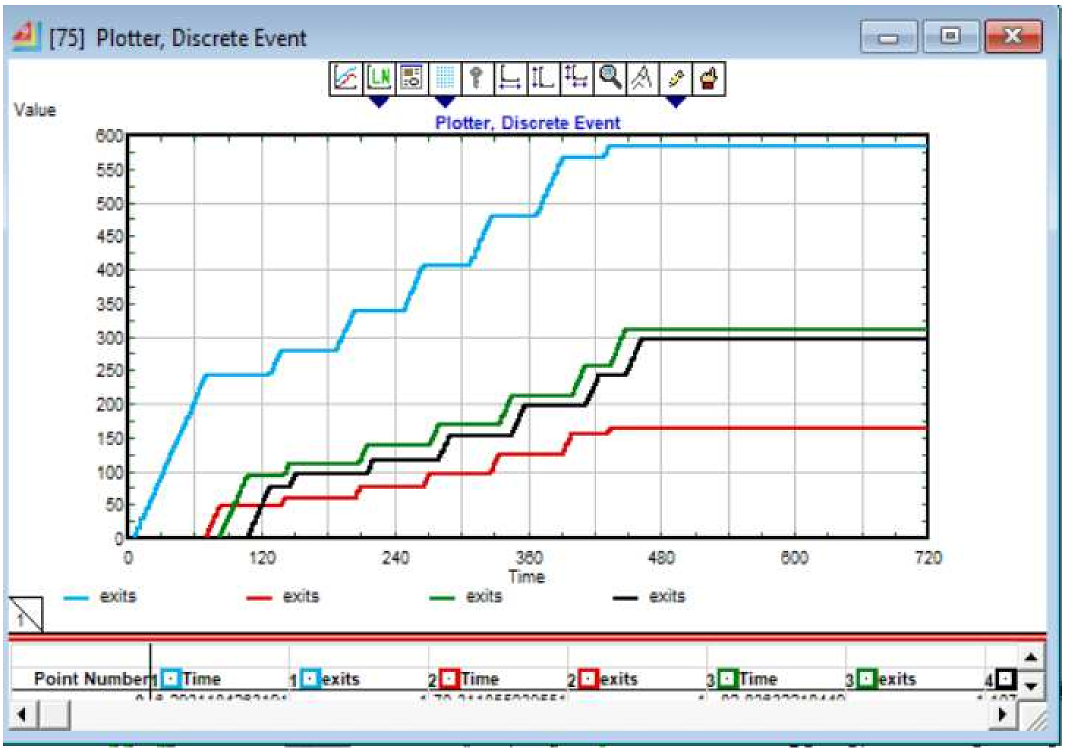

Figure 4 Result of proposal No. 1 for transport companies (Cargus, GLS HR, Zásielkovňa , PPL)
Cargus, GLS HR, Zásielkovňa, PPL

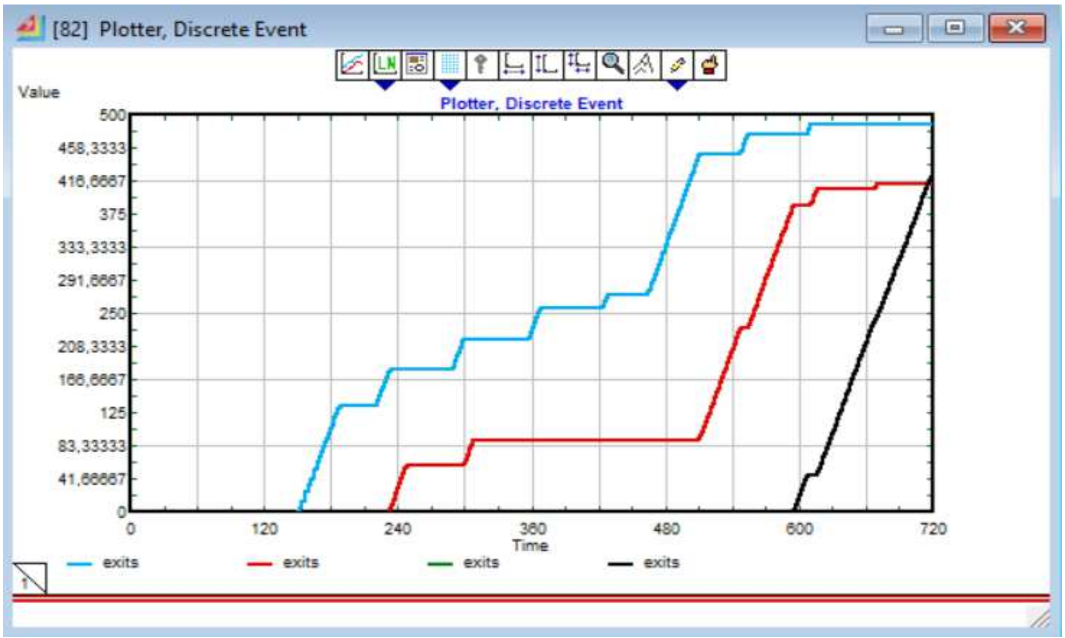

Figure 5 Result of proposal No. 1 for transport companies (GLS HU, Post, DHL)
GLS HU, Post, DHL

Experimenting with the deployment of employees, we came to the conclusion that the optimal solution is 15 people on Picking and 13 people on Packing. The advantage of this proposal is that the company does not have to spend any funds to hire more employees. The disadvantage is the high workload, which represents 98% at the Picking and 93% at the Packing (Figure 3). Another disadvantage is the small time reserve, which means that the system operates in a highly tense mode. From the graphs in Figure 4 and Figure 5, we can see that all orders were packed but just before the time limit. An unexpected increase in orders would mean that the warehouse would not be able to ship all orders, which would lead to non-delivery of the order and cause customer dissatisfaction.

3.2 Proposal No. 2 with an increased number of employees

The second proposal simulates a system with an increased number of employees. The setting of times in individual "Activity" blocks is the same as in proposal 1. In this proposal, we have increased the number of employees at Picking by 3 and at the Packing by 2. A total of 33 workers are employed in this proposal. The result is a reduction in Picking utilisation from 98% to 82% and Packing from 93% to 80%. The utilisation of "Activity" blocks in proposal 2 is shown in Figure 6.

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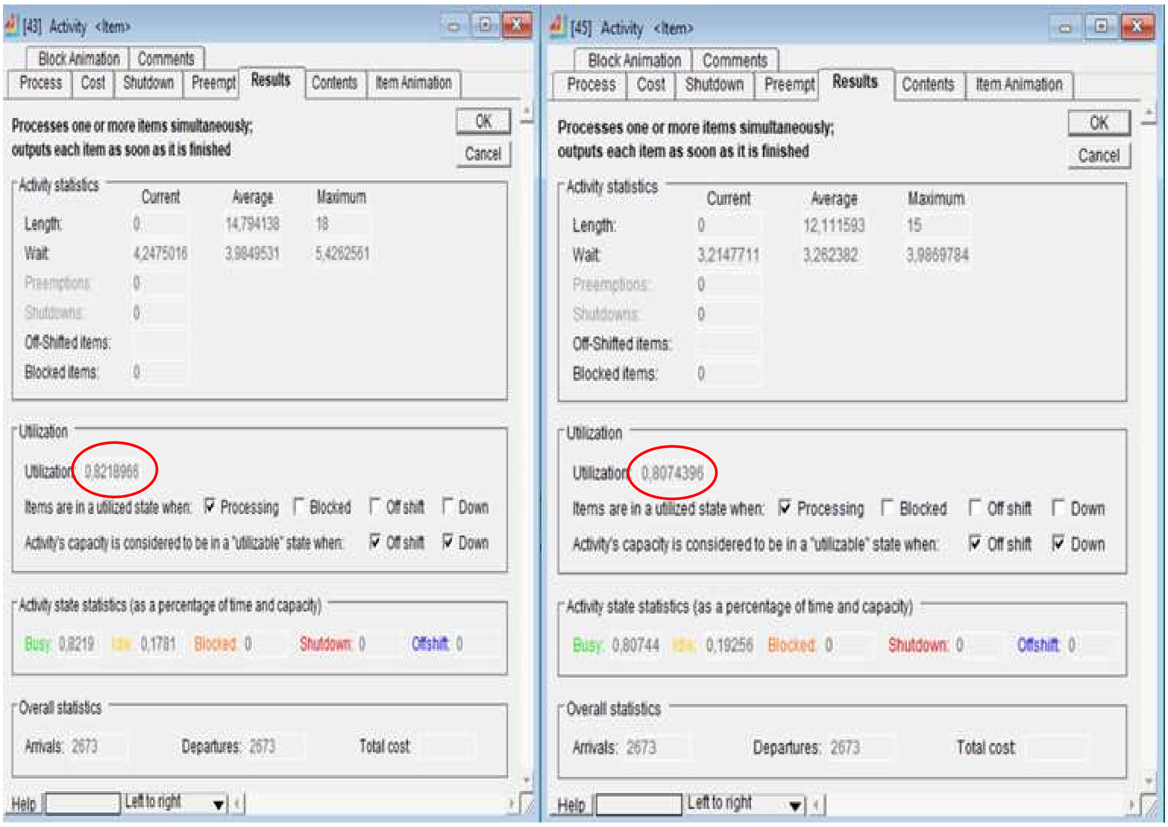

Figure 6 Use of activity-Picking and packaging blocks in proposal No.2

Figure 7 and Figure 8 show the course of the simulation in proposal 2, where the colour curves represent the packing times of orders for individual transport companies and the vertical axis shows the number of orders. The graphs show that the time reserves are much larger than in proposal 1.

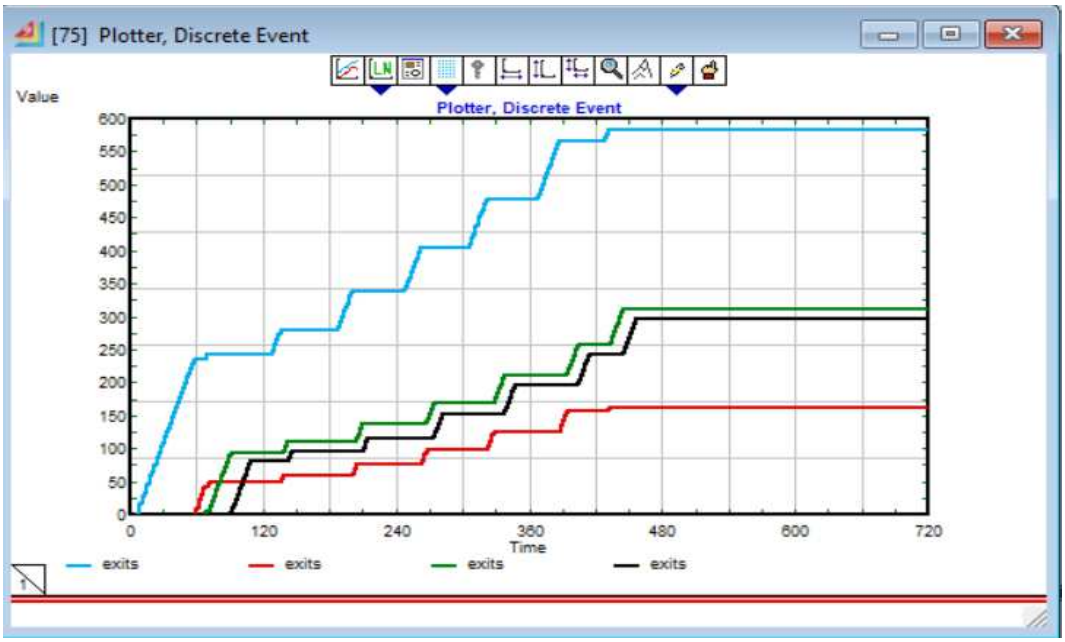

Figure 7 Result of proposal No. 2 for transport companies (Cargus, GLS HR, Picking, PPL)
Cargus, GLS HR, Zásielkovňa, PPL

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The advantage of proposal 2 lies in the reduction of the workload of employees and in the creation of larger time reserves. The graphs and Table 3 show that the time reserves have increased significantly compared to the first proposal. Such system can withstand an unexpected increase of orders by about 300. The disadvantage of this proposal is that the company would have to hire another 5 employees, which would result in an increase in labour costs.

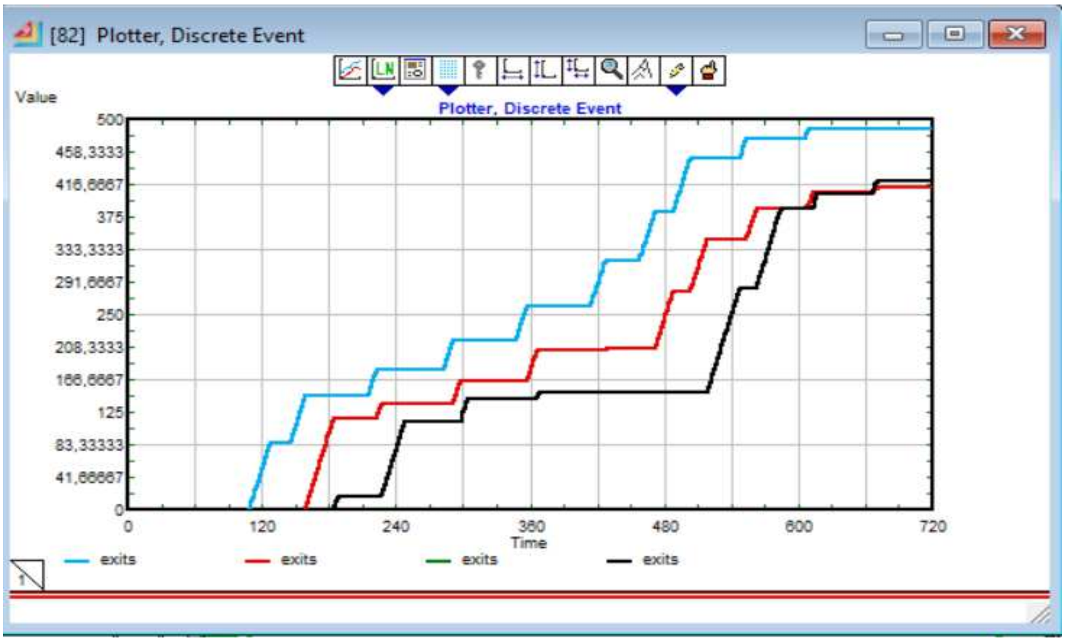

Figure 8 Result of proposal No.2 for transport companies (GLS HU, Post, DHL)
GLS HU, Post, DHL

Table 3 Packaging times of the last package for individual transport companies in proposal No.2

Transport company	Packing time of last order
Cargus	13:06
GLS HR	13:18
Zásielkovňa	13:40
PPL	13:50
GLS HU	16:10
Post	17:12
DHL	17:20

The analysis of activities in the warehouse showed that the company has a problem in the organisation of work in the warehouse, specifically a bottleneck in the picking section. The problem in the organisation of work was caused by the uneven distribution of employees in the picking and packaging departments. To overcome this problem, two proposals were verified by ExtendSim9 simulation program to find the optimal allocation of workforce into workplaces.

Proposal 1 considered the currently available number of workers, while the simulations examined the possibilities of dividing the workers into the picking and packaging department. The simulation results provided information on the optimal distribution of staff, which eliminated the bottleneck. The total number of employees 28 was in the optimal solution divided into 15 people for picking and 13 people for packaging. In this mode, the system managed to meet the requirements, all orders managed to be packed on time. However, the workload of picking workers was 98% and packaging 93%. The advantage of this proposal is that the company does not have to spend any funds to hire more employees. The disadvantage is the high work commitment and small time reserves, which would, in the event of an unexpected increase in orders, cause the warehouse not to be able to ship all orders.

Proposal 2 considered an increased number of employees. The aim of this proposal was to remove the bottleneck and at the same time reduce the workload of workers to about 80%. In case of unexpected delays and sudden increases in orders, this burden creates enough reserve time. Repeated experiments on the simulation model have provided a solution for the optimal distribution of workers in increased numbers. The results of the simulation showed that if we increase the number of workers in picking by three and in the packaging by two, the utilisation rate in picking will decrease to 82% and in packaging to 80%. In such a work schedule setting, the system would be able to withstand an unexpected increase in orders of approximately 300.

By comparing both proposals only based on direct costs, proposal 1 is a more appropriate solution to the bottleneck problem. It does not require any additional costs, and by a simple organisational change, the bottleneck can be eliminated. In terms of the overall risk of the assessed system, indirect costs, and concerning sustainability, the solution according to proposal 1 is unacceptable, or acceptable only in the short term. The analysed company is therefore forced to seek a solution to the bottleneck by increasing capacity. This is either by increasing the number of own employees, by relocating workers from other workplaces, if possible, or by hiring labour force for exposed periods. Another possibility of eliminating the bottleneck is investing in the modernisation of the used technologies.

4 Conclusions

Capacity constraints determine system performance. Simulation programs are often used in solving capacity problems and bottlenecks elimination. The article dealt with the issue of bottleneck elimination in the distribution warehouse using computer simulation. The initial analysis of the processes identified the bottleneck at one of the warehouse workplaces (packing), which led to the risk of non-compliance with the requirements for sending orders within the time limit. The reason for the creation of the bottleneck was preliminarily determined by the unbalanced distribution of warehouse workers to workplaces. Based on the determination of time and capacity parameters of the process, a simulation model was created in the ExtendSim9 program and the warehouse process was simulated. Experiments with a different redistribution of employees were used to find the optimal solution so that the process is managed, and workload allocation is optimal.

The simulations resulted in two proposals for staffing the Picking and Packing sites. In the first proposal, the current number of workers was considered 28, the optimal solution was to put 15 on picking and 13 on packing. However, based on simulations, this solution would mean mastering the process (all orders are sent on time), but the workload of employees would be 98% (picking) and 93% (packing) and even with a small increase in orders, the process would be unmanageable. In the second solution, an increased number of employees was considered and in order to achieve not only the mastery of the process but also the optimal load of workplaces (approximately 80%). This solution requires increasing the number of workers for picking by 3 and for packing by 2.

The advantage of the used method is solving the problem on the virtual simulation model and verification of the impacts of the proposed solutions in advance and practically with no financial costs. But several limitations also need to be pointed out. The simulation model is still a simplification of reality and does not take into account many, even significant factors. Work productivity and workplace performance depend not only on the number of employees and the production volume but also on the motivation, skills, and qualifications of the workforce. Also, the work environment and workplace equipment affect the performance provided. These factors have not been included in the presented simulation model.

Acknowledgement
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IMPACT OF THE PANDEMIC COVID-19 TO CRIMINAL ACTIVITY IN TRANSPORT

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Keywords: crime, transport, COVID-19, good, loss
Abstract: 2020 has been a year like no other for most of us, dominated by a virus that has cost over 1.15 million lives globally and plunged the world into an economic recession which the Chief Economist of the World Bank says it could take five years to recover from. For business leaders in every sector, over the past six months it has been almost impossible to focus on anything but finding the most sustainable way through this sudden and unexpected crisis – and, for most, it will be hard to think about anything else for a long time to come as they battle to protect the futures of their organisations. Against such a dramatic and damaging backdrop, every business can be forgiven for letting Covid-19 dominate their thinking. They have shareholders to satisfy, customers to support and jobs to protect. Right now, the very survival of companies of every size remains in the balance with no end date in sight to the current crisis. The pandemic has not stopped the crime either, we can eve say that the number of criminal activities has increased. In this article, we want to point out the difference between criminal activity in transport at the beginning of 2019 compared to 2020. The statistics are taken from the international database of criminal activities processed by TAPA EMEA.

1 Introduction

COVID-19 has created drastic shifts in the supply chain landscape. Corporations have been forced to seek quick alternatives to manage closed borders, blanks sailings, flight cancellations and quarantine requirements to keep their supply chains moving. As such, supply chains face new and often uncalculated risks emerging from adjusted cargo routes and switching of transportation modes across the APAC and EMEA regions.

Safety and security are the primary interest of every transport system. Transport safety is a sensitive issue that affects all transport users and transport providers. It is a fundamental right to travel without fear of falling victim to some form of attack. However, it is also important that safety is not so disruptive as to make transport an unpleasant experience. Fortunately, terrorist acts are isolated events, but it must be in mind that transport is a popular destination for such events. Although such an event may be rare, the risk remains and reveals vulnerabilities throughout the transport supply chain. Other forms of transport security threats are more common: crimes committed on the premises of carriers (such as burglary), black passengers, robbery of securities during transport or piracy on the high seas. These have huge economic costs that can be measured in the range from the cash value of cargo theft to insurance losses, downtime and property damage [1-4].

1.1 Global cargo crime trends

According to new research, the insurance company has the largest cargo theft in the world in the field of freight transport, whether it is a criminal activity during transport or in a parking lot. In the following picture we can see a comparison of the total criminal activity in transport for selected years in the EMEA region (Europe, Middle East and Africa). Most crimes occurred in Germany, France and the United Kingdom [5-7].

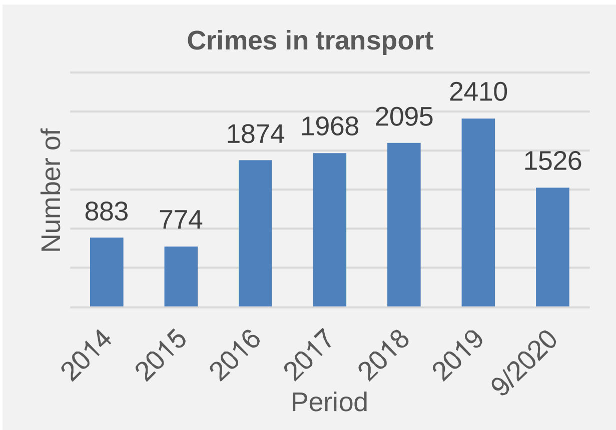

Figure 1 Number of crimes in transport in EMEA region [authors, 8]

If we look at the type of criminal activity, it is shown in Figure 2, so the most common criminal activities are theft from vehicle, theft of vehicle, theft of container or robbery.

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This is followed by theft from facility, fraudulent pick up, hijacking, etc. [9,10].

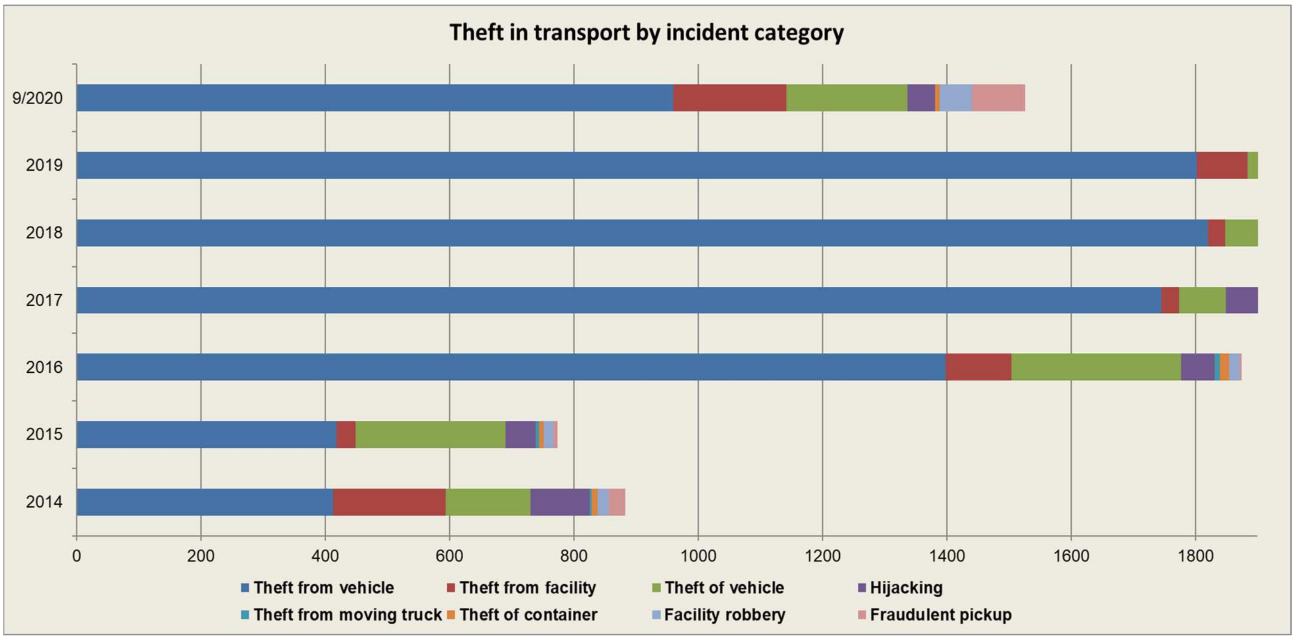

Figure 2 Theft in transport by incident category [authors, 8]

There are different ways of parking on roads in Europe, in compliance with the Regulation 561/2006 or the AETR agreement (required rest of professional drivers). Some use regular public car parks, others park on the side of roads, while those more responsible rely on security car park services [11,12]. The biggest problem is parking in unsecured parking lots. Drivers use unsecured parking areas because there are few safe parking lots around the world. Their number in this period is 7500, which is absolutely insufficient with the growing number of road freight transport [13,14].

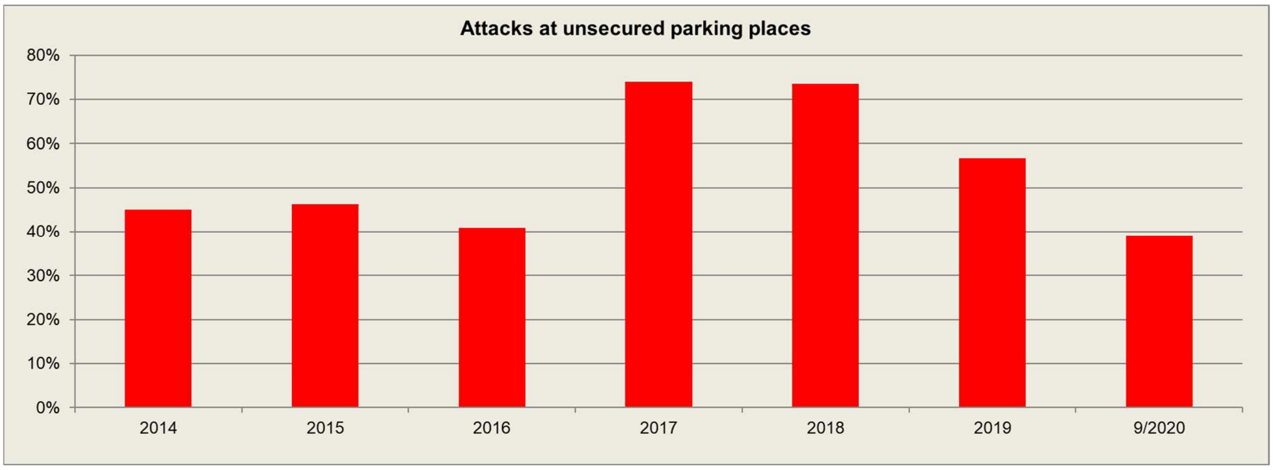

Figure 3 The number of attacks at unsecured parking places [authors, 15]

1.2 Impact of the pandemic on crime

Any idea that cargo thieves would be less active when the coronavirus crossed international borders quickly dispelled the 469 supply chain thefts recorded in two months, with several countries most affected by the virus recording the highest rate of cargo losses [8].

Only 120 or 25.5% of the accidents recorded in the IIS TAPA during this period had a combined value of the loss of stolen goods, resulting in a lower than average number of thefts of large cargo. A total of six were recorded, causing a total loss of EUR 1 671 876 or an average of EUR 278 646. For all accidents with a value, the total amount increased to EUR 2,952,303 or on average to EUR 24,602.

Out of a total of two months, 321 crimes were reported in February TAPA EMEA and 148 in March.

In the next Figure 4 we can see The IIS heatmap tool, which shows the intensity of cargo crimes in the UK and the Netherlands in the month of February 2020. Germany recorded the highest number of cargo thefts in the IIS database in February and March with 137 crimes, followed by the United Kingdom with 112.

In the next Figure 4 we can see The IIS heatmap tool, which shows the intensity of cargo crimes in the UK and the Netherlands in the month of February 2020.

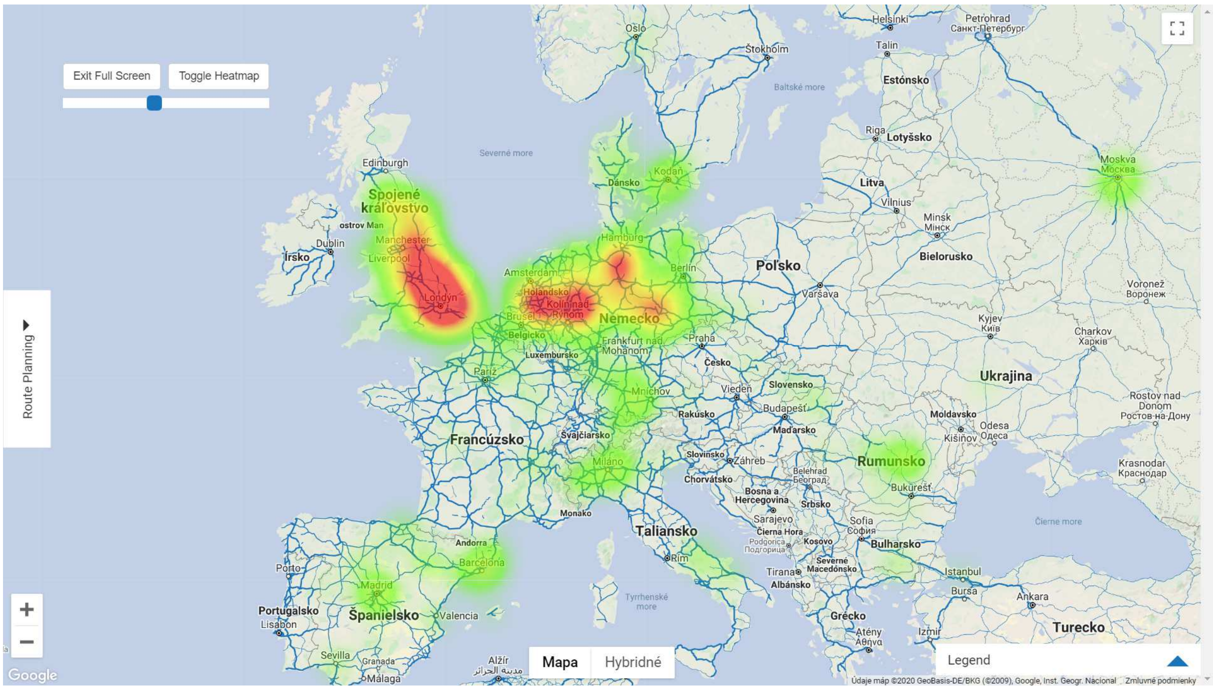

Figure 4 The intensity of cargo crimes in the Europe in February 2020 [authors, 6]

More than half of the crimes with cargo were recorded. The statistics on crimes of violence or threats of violence were also remarkable, with 42 incidents in this category representing 8% of the total number of February-March.

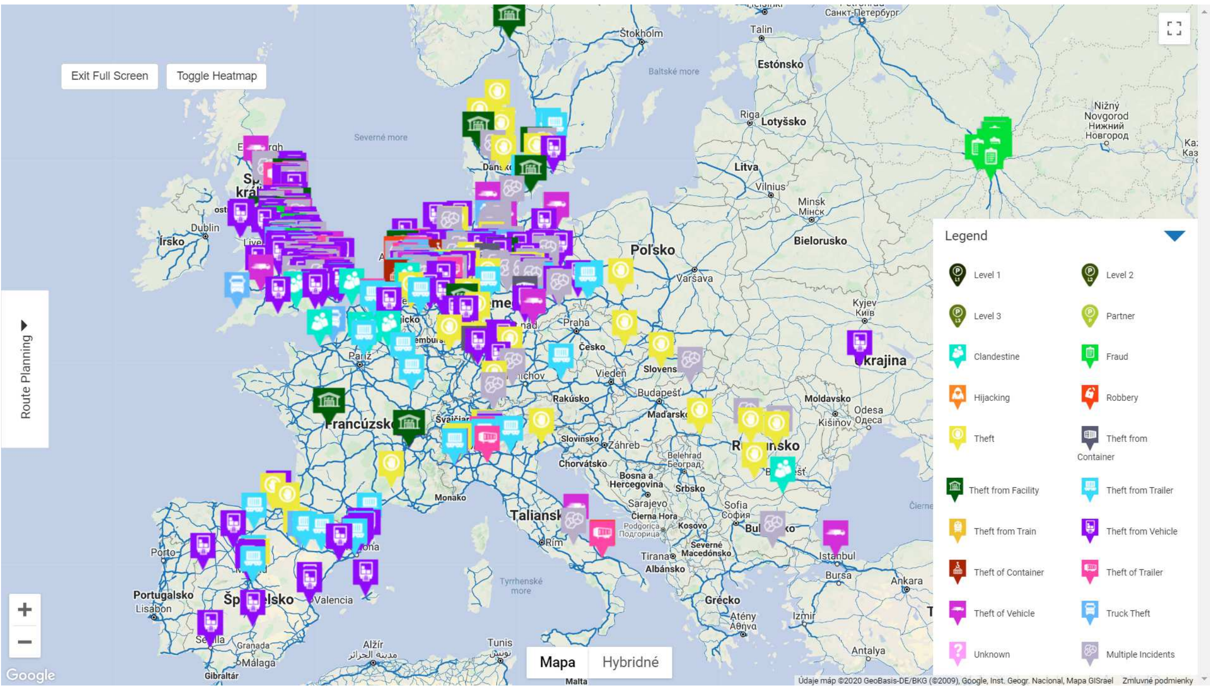

Figure 5 The type of crimes in Europe in February 2020 [authors, 8]

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If we compare only two months February and March in 2019 and in 2020, then we can see the following facts.

In February 2020, 963 crimes were reported, of which only 545 reported damage to goods amounting to more than EUR 17.5 million. 562 cases occurred on the road or in an unsecured parking area. Great Britain (388) and Germany (273), followed by Spain and France, recorded the most cases. In March 2020, 625 crimes were reported, of which only 393 reported damage to goods amounting to EUR 36.5 million. 309 cases occurred on the road or in an unguarded car park. Great Britain (695) and Germany (413) recorded the most cases, followed by France and Spain.

If we compare these data with the same period in 2019, so we can see that. In February 2019, 1385 crimes were reported, of which only in 660 cases did they report the amount of damage to goods, which amounted to more than EUR 19.8 million. 842 cases occurred on the road or in an unsecured parking area. Germany (407) and Great Britain (278) recorded the most cases, followed by Spain and France. In March 2019, 1352 crimes were reported, of which only 528 reported the amount of damage to goods, which reached the limit of EUR 25.8 million. 819 cases occurred on the road or in an unguarded car park. Great Britain (422) and Germany (293) recorded the most cases, followed by France and Spain.

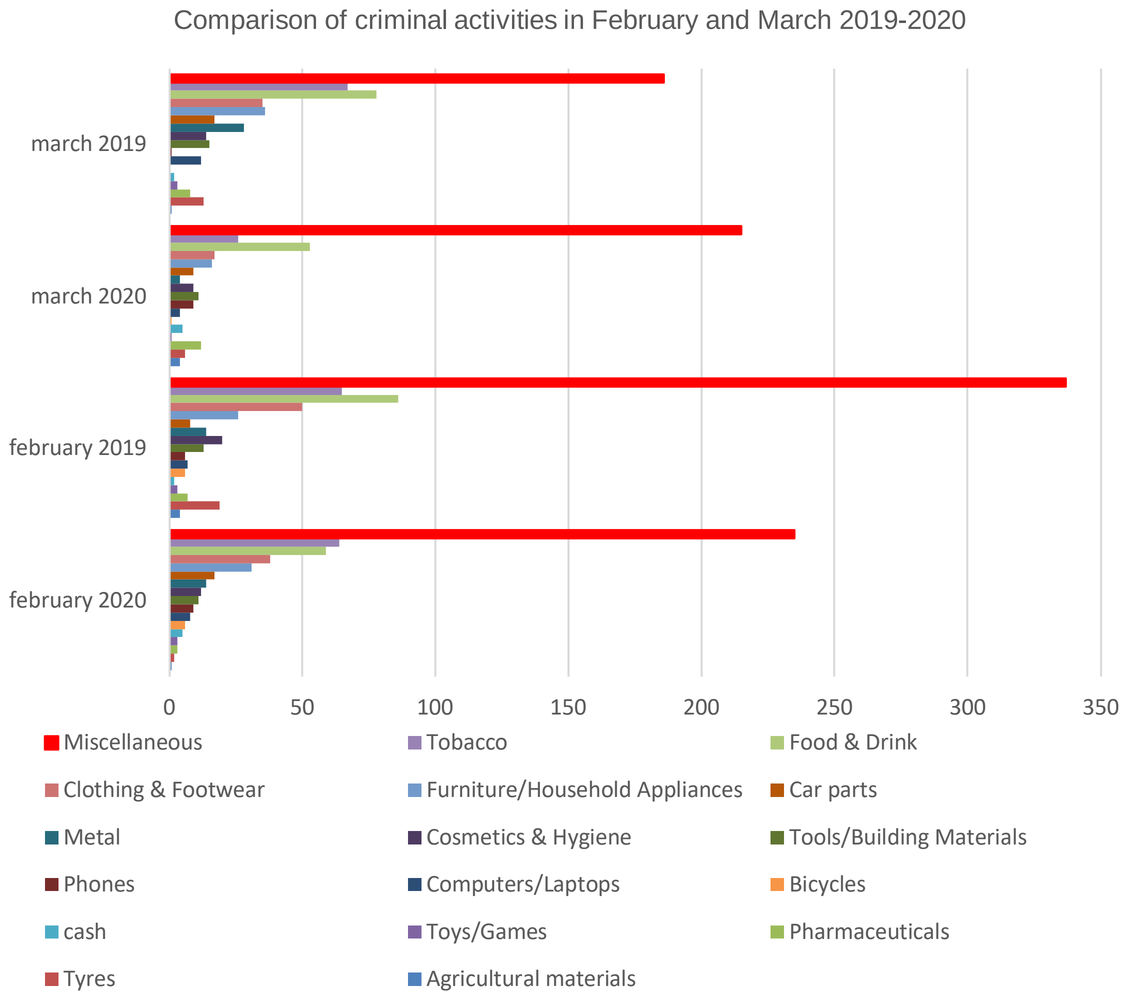

Figure 6 The type of crimes in Europe in February 2020 [authors, 8]

As we can see from the graph (Figure 6), there were more incidents in selected months in year 2019 than in year 2020. Among the most stolen specified goods were miscellaneous, food and drinks and clothing and footwear. The only change was the type of goods in March 2020, when there was an increased theft of protective equipment.

The supply and demand nature of the black market for stolen goods also prompted a spate of thefts of Personal Protective Equipment as offenders looked to cash in one of the most sought-after products to help fight the outbreak of the coronavirus. In addition to the €5m theft of face masks previously highlighted in Spain, TAPA's IIS was also notified of cases involving:

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- Millions of respiratory masks stolen from an Aviation Transportation Facility in Kenya on 20 March.
- 680,000 face masks from an unknown location in the Czech Republic on 17 March.
- 500,000 face masks taken from a truck in France as it headed to towns across the Spanish border on 7 May.
- 200,000 face masks disappeared from a truck parked at a motorway service area in Spain on 8 May.
- 50,000 medical suits were taken from a shipping warehouse in Turkey on 7 April.
- 50,000 respirators from a Destination Facility in Cologne, Germany, on 16 March.
- A shipment of hand sanitiser from a truck at a MSA in Odsmalsbron in Sweden on 6 April.
- Boxes of facemasks were taken from an Authorised 3rd Party Facility in Moscow on 19 March.
- Protective medical gowns and gloves from an Authorised 3rd Party Facility in Bergen, Norway, on 20 March.
- Protective face masks from a vehicle in Coulounieix-Chamiers in France on 18 March.

Demand for another highly publicised type of product during the lockdown was also reflected in the theft of 130,000 toilet rolls from trailers in Walsall in the United Kingdom on 20 March [10].

2 Result and discussion

It is also clear from the following figure 7 that in 2019 more criminal activities were recorded in the EMEA database than in 2020. The reasons may vary:

- the victims did not report the crime to the Tapa EMEA database,
- worldwide lockdown and restrictions on the movement of persons have also affected the number of thefts of goods,
- fewer goods were transported, due to closed companies at the beginning of the year,
- thieves have focused on cyber space.

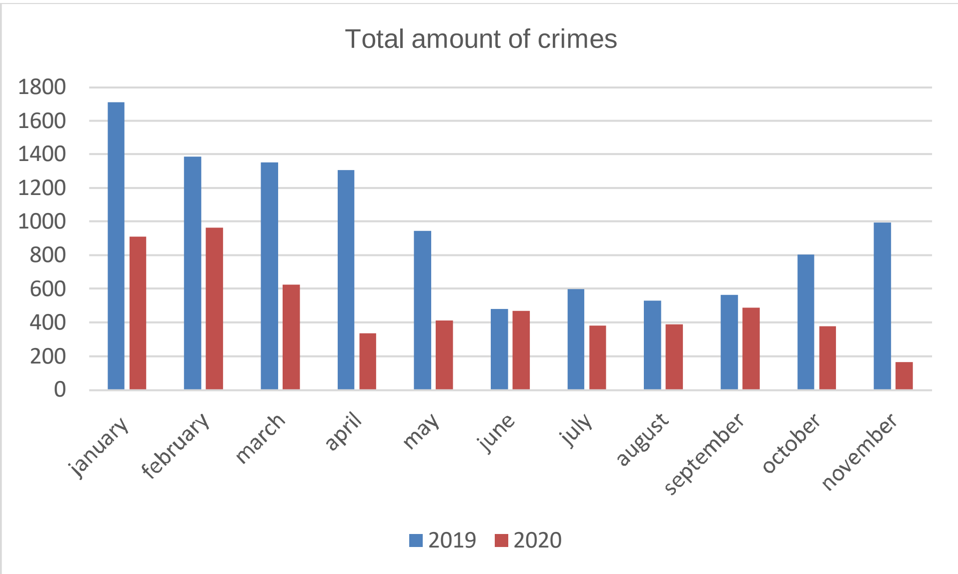

Figure 7 Total amount of cargo crimes in 2019 and 2020 [authors, 8]

Everybody believe most of these major crimes are being conducted by Organised Crime Groups who, far from being locked down by a pandemic or fearful of getting overtaken by next generation technologies, are still going about their very lucrative business and reaping substantial rewards for their efforts. At a time when our world and businesses feel like they are being turned upside down and may never be the same again, we must not lose sight of the fact that for the perpetrators of crimes against carriers, pandemic or no pandemic, it's business as usual using very simple and traditional methods to attack supply chains.

3 Conclusions

Cargo theft may not be a major problem during a pandemic, but when bad things happen, bad people can find opportunities. We saw the disappearance of medical mask shipments. Cargo crime occurs in places that are not typical, such as Hong Kong, because supply chains are redirected and some products have priority, which affects their value. One example is medical masks, but hand sanitizer and toilet paper - which are not usually high-priced but currently in short supply - are attractive products for cargo thieves that can be stolen and resold. The impact of coronavirus pandemic 2019 (COVID-19) is one of the biggest threat's companies have seen during the year for supply chains due to its ubiquity and potential duration. But from the point of view of the amount of stolen goods in the transport chain, we can see that measures to restrict the movement of people have also caused a lower number of stolen goods.

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THE DRIVERS AND BARRIERS OF GREEN SUPPLY CHAIN MANAGEMENT IMPLEMENTATION: A REVIEW

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Keywords: green supply chain management, drivers, barriers, literature review
Abstract: Due to environmental degradation such as climate change, increased CO2 and GHG emission and all other problems threatening the world and its existence. Firms now are forced to think about integrating environmental thinking into their business operations in order to satisfy their stakeholders. Therefore, several organizations start developing environmental management strategies such as green practices overall their business operations, and since the supply chain concerns the product from its initial processing of raw material until the delivery to the customer there has been an emergency to integrate environmental thinking within this function. This paper aims to review the literature on the drivers and barriers influencing GSCM implementation. A total of 60 elements that englobe 28 drivers, and 32 barriers were identified from the selected literature where only the highest weightage factors are discussed. As results, Financial and cost related factors, Customers and Regulatory related factors seemed to behave simultaneously in both directions.

1 Introduction

Currently and all over the past decades, governments, organizations, companies, communities, policymakers, individuals and researchers are all increasingly focused on the subject of sustainable development [1] due to the environment degradation such as climate change, pollution, increased CO2 and GHG emission, global warming, and all other problems threatening the world and the human race existence [2-5]. Nevertheless, several efforts have been made by international agencies and national governments in order to protect and reduce these challenges [4] as results, industries and manufacturing firms are the first to face these problems due to their involvement as being a major actor in making natural, environmental and ecological issues [1,6]. However, these issues turned out to be critical and crucial for firms in order to satisfy their stakeholders requests such as customers, authorities, workers and associations that are increasingly requesting from firms to include environmental and social sustainability in their business operations and to fit in with the environmental standards [5,7].

In this manner, so as to keep up the same level of production and at the same time to respond to their stakeholder's requests, firms must adapt an alternative way of managing manufacturing operations, such effort involve huge changes and adjustments in the process of production and the supply chain planning [4]. Therefore, organization are now forced to think about integrating environmental thinking into their business operations in order to ensure and generate competitive advantage, to get adapted to the various environmental regulations across regional, national and international dimensions [3].

Therefore, several organizations have started developing environmental management strategies such as green practices all over their business operations including implementation of environmental audits, maintaining environmental management system certifications (14001 ISO) and cooperating with their stakeholders in order to respond to these changes and to fulfil environmental obligations [3,8]. Thus, since the supply chain concerns the product from its initial processing of raw material until the delivery to the customer there has been an urgency for firms to integrate environmental thinking within this function [9]. In this context, integrating an environmental thinking into the SCM has got a huge attention from multinational firms, what gave birth to a new leading concept named as The Green Supply Chain Management [1]. Nevertheless, this concept has received an enormous attention by scholars since the late of 80's and it has become more established during the mid of 90's [10]. Accordingly, the GSCM has been treated by several academicians from different perspectives and dimensions. At the same level, [11] claims that there is an ambiguity when it comes to define the GSCM. Thus, a range of possible definitions of the GSCM have been developed over the past decades, according to Scopus database, one of the most highly used definitions of GSCM is given by [12] who considers it as "integrating environmental thinking into supply chain management, including product design, material sourcing and selection, manufacturing processes, delivery of the final product to the consumers, as well as end-of-life management of the product after its useful life." At the same level, Beamon (1999) as cited by [13] defines the GSCM as "the extension of the traditional supply chain to include activities that aim at minimizing environmental impacts of a product throughout its entire cycle, such as green design, resource saving, harmful material reduction, product recycle and reuse." Following the same way, [3] GSCM refers to "the combination of environmental, societal and economic consideration in a supply chain which operates as linked activities starting from sourcing raw materials to post consumption activities of products or services by the customers". Hence, in order to understand this emerging phenomenon, several efforts have been made by researchers during the last decades in identifying the drivers and barriers for GSCM implementation.

Thus, this study aimed to identify and classify the major drivers and barriers influencing GSCM implementation using articles published in periodicals, these drivers and barriers are further classified into two subgroups: internal and external.

This paper is prepared as follows: Section 2 presents a literature review of GSCM implementation among different industries. Section 3 illustrates the followed research methodology. The classification of the drivers and barriers of GSCM implementation are presented in section 4. The discussion and findings are presented in the section 5. Finally, Section 6 presents the summarized conclusion.

2 Literature review

In the last few decades, several authors have made enormous efforts to identify the drivers and barriers of GSCM implementation among different industries and contexts, for example, Towbridge [14] Evaluates the operations of environmental supply chain management among advanced micro devices companies, claiming that GSCM in AMD is driven by both internal and external factors, such as NGO's and organizational risk management. [15-17] pointed out in their research while evaluating drivers, practices and performance within Chinese manufacturing companies that these firms are driven by several factors such as regulation, costs and exports. Walker et al. [18] while investigating drivers and barriers among private and public-sector organizations found that organizations appear to be influenced by external drivers such as customer, regulation, etc. more than internal related factors, on the other hand Cost Related Factors, legitimacy and regulation are considered as the most significant barriers. Lee [19] investigated the SMEs supplier's and concluded that these companies are driven by 3 different factors such as Buyer influence, Government involvement and Green supply chain readiness. Diabat and Govindan [20] identified and ranked 11 drivers such as Environmental collaboration with suppliers, Collaboration between product designers and suppliers to reduce and eliminate product environmental impacts, Government regulation and legislation, by using an Interpretive Structural Modelling (ISM). Hsu et al. [21] used the institutional theory in order to identify the drivers of GSCM among Malaysian firms, the investigated drivers are the following: Coercive and memetic isomorphism, Normative isomorphism and Cultural-Cognitive isomorphism, the authors claim that COmpetitor pressure is the most significant driver, while SOcio- cultural responsibility is the lowest. Xu et al. [22] identified 32 drivers from the literature and classified them into five categories such as: Regulation, Market and competitiveness, External factors from suppliers, Financial factors, Production and operation factors. The authors found out in their comparative study that each industry has its own pressures. Khiewnavawongsa and Schmidt [23] in their research on the barriers of GSCM implementation among electronics industry, the authors identified 33 barriers from the literature and categorized them into 6 factors, Supply chain, Economy justification, Perception, Motivation, Implementation and the Resources limitation. The study claims that the most significant factor affecting green initiative adoption was from financial concern. Dashore and Sohani [24] reviewed the literature on the drivers and barriers of GSCM implementation, the authors identified 20 barriers from various industries, such as, absence of IT system incorporation, weak GSCM organizational culture, Lack of experienced human resource, Uncertainty and market rivalry, Absence of government initiatives, Low GSCM practices implementation, etc. and 16 drivers, namely, Suppliers' environmental management system certification, Firm's environmental collaboration with their suppliers, Diminution and removal of harmful products through collaboration between product designer and suppliers, Government regulation and legislation, Recognition from Third part (certification, ISO 14001), etc. Otherwise, Somsuk and Laosirihongthong [25] have used 3 theoretical backgrounds, namely, Resource Based View Theory, Relational View, and Institutional Theory, to identify and rank the drivers of GSCM implementation among organization in Thailand, however the drivers are classified by the following: RBV (Internal drivers: Top management support, Waste and Pollution reduction, Cost reduction) Institutional (External Drivers: Government, Customers, Competitors, Society) and Relational Drivers (Employee involvement and motivation, Customers and suppliers collaboration, Knowledge sharing in supply chain, Company's green image and reputation) the study claims that the most influential drivers are: Government initiative, Top Management support, Customer pressure, Cost Diminution, Pollution Reduction.

In a nutshell, several empirical investigations have been done to understand the pressures and barriers that affect the adoption of green supply chain management practices within firm's supply chain activities. Therefore, Table 1 briefly summarizes the identified drivers and barriers from the extant literature.

Table 1 Drivers and Barriers of GSCM implementation investigated in previous researches

	Sr.N°	Elements	Authors
Drivers	1	Foreign and Local Customer (Including Export, Environmental collaboration with Customer, Customer awareness)	[8,14-22,24,25,27,30-33,35,37,39-41,43,44,46,47,52-59]
	2	Regulation (Including Government, Local, National and International, Importers regulation, Products potentially conflict with laws)	[8,15-22,24,25,27,30-37,39-41,39-41,43,46,47,52-55,57-59]
	3	Society, NGOs and Media	[14,18,22,25,28,31-33,35,37,38,41-43,46,52-54,58,59]
	4	Financial and Cost related	[15-18,24,25,31-35,47,52,53,56-59]
	5	Competitors	[15,16,21,22,25,27,30,32,33,37-39,41-43,47,52,53,59]
	6	CSR and Company environmental mission	[15,17,21,22,27,28,30-33,35,39,41,52,53,57-59]
	7	Suppliers related factors (Collaboration with supplier, Certification of suppliers and characteristics)	[14-17,20,22,24,25,31,35,37,39,41,43,46,59]
	8	Top Management Support Commitment and Leadership	[25,27,28,31,35-40,42,46,53,57]
	9	Green image and firms' reputation	[22,24,25,27,31-35,39,52,53,57]
	10	Recognition from Third part and Implementation of EMS, TQMS	[20,22,24,29-31,34,39,41,46,47,53]
	11	Employees	[25,29,31,35,38,41,42,52,57]
	12	Green Knowledge, Technology, Firms capabilities	[16,19,20,25,31,33,40,46,57]
	13	Organizational values and firms desire	[15,18,31,40,44,46,53,58]
	14	Internal Policy	[16,17,27,28,36,40,47,59]
	15	Green practices related factors	[20,24,25,37,47,53,57]
	16	Investors	[14,31,41,52-54,59]
	17	Potential liability for disposal of harmful materials	[16,17,22,32,41,59]
	18	Innovation	[31,34,39,43,47]
	19	Competitive advantage	[18,31,55,59]
	20	Internationalization	[8,22,31,53]
	21	Policy Entrepreneurs	[18,22,41,59]
	22	Owners /shareholders	[22,31,52,59]
	23	Organizational Risk Management	[14,18,22,53]
	24	Corporate strategy	[14,31,37,40]
	25	Performance improvement	[33,41,59]
	26	Quality improvement	[47,59]
	27	Global Climate Pressure	[52]
	28	Industry orientation	[22]
Barriers	29	Financial and cost related factors (cost of implementation)	[23,24,26-29,32,41,45,47-51]
	30	Regulatory related factors (Government, Government fiscal incentive, International trade association)	[18,23,24,26,28,29,32,41,45,47-51]
	31	Supplier related factors (Flexibility to change, Unawareness, Certifications, Lack of green suppliers, Price, Integration, Source of eco-friendly materials, No proper rewarding system to suppliers)	[18,23,24,26,27,29,32,41,45,47-51]
	32	Lack of resources (Human and financial)	[18,23,24,26,28,29,32,41,45,48-51]
	33	Customer related factors (Lack of Customer demand, Unawareness, Lack of pressure, Price)	[23,24,26,27,29,32,41,45,48-51]
	34	Lack of Top Management Commitment	[24,26,29,32,41,45,48-51]
	35	Organizational Culture and CSR adoption	[24,26,28,29,32,41,45,49,51]
	36	Lack of knowledge and green technology adoption	[24,26,28,32,41,45,48]
	37	Lack of integration of IT system	[24,29,32,41,45,49]
	38	Competitiveness related factors (Price)	[23,24,41,45]
	39	Lack of Green practices adoption	[24,29,45,48]
	40	Difficulties in identifying and measuring costs/benefits	[27,48,50]
	41	Difficulties in identifying Environmental Performance Metrics	[29,48,50]
	42	Industry	[18,28,41]
	43	Lack of Society pressure and awareness	[32,41,49]
	44	Employees Resistance	[18,29]

	45	Complexity of design to reuse/recycle used products	[48,50]
	46	Fear of Failure	[29,48]
	47	Corruption	[28,32]
	48	Lack of bank encouragement (Loans)	[48,49]
	49	Lack of Green System exposure for professionals	[24,48]
	50	Competition and market uncertainty	[24,49]
	51	Lack of Certification	[24]
	52	Strategic planning	[29]
	53	Complexity in identifying 3rd parties to recollect used products	[48]
	54	Lack of sustainability Internal audits	[32]
	55	Technical obstruction with implementation of GSCM	[51]
	56	Lack of legitimacy (compliance)	[18]
	57	Global Financial Crisis	[29]
	58	Innovation and scientific research	[49]
	59	Internal and intermodal transport	[49]
	60	Lack of promotion of green materials in local markets	[51]

3 Research methodology

An in-depth review of the literature on GSCM was carried out to distinguish and classify the most potential related factors that impact GSCM practices implementation among different industries. This study follows the work of [32,33,41]. Many journal papers, conference proceedings and theses have been selected. The collected data from the literature are classified into two subgroups: internal and external, drivers and barriers. The ranking is based on the frequency of citation.

4 Classification of the drivers and barriers of GSCM implementation

The last few years have witnessed a growing interest in examining the drivers and barriers of GSCM implementation in different contexts and industries. Several authors [9,14-22,26-33] have worked on the area of identifying the factors that push or hinder firms to adopt green practices within their supply chain.

Simultaneously, firms tend to develop environmental strategies due to the increased concern about environmental issues that we are facing nowadays [56].

Hence, they are driven by several elements to adopt green strategies within their supply chain activities. In line with this trend, several empirical investigations [9,14-19,25,27,33-38,40-45] have identified and classified the drivers into two categories: internal and external drivers, the formers could be defined as the motivators that comes from the firm itself [41]. These drivers include internal policies and firm awareness, employees, middle and senior managers desire and commitment, firms environmental strategy (corporate social responsibility) and organizational values, cost reduction desire, performance improvement desire, investors pressure, etc. otherwise, the latter's could be defined as the pressure that comes from the external environment, as for example government regulation, public opinion, competitors, suppliers, consumers and multinational corporate partners as in [15-18,36-38,42]. Therefore, the tables 2 and 3, summarize, classify and rank the drivers of GSCM implementation.

Table 2 Internal drivers that affect GSCM implementation investigated in previous researches

Rank	Internal Drivers	Number of citations	Authors
1	Financial and Cost related	20	[15-18,24,25,31-35,47,52,53,56-59]
2	CSR and Company environmental mission	18	[15,17,21,22,27,28,30-33,35,39,41,52,53,57-59]
3	Top Management Support Commitment and Leadership	14	[25,27,28,31,35-40,42,46,53,57]
4	Green image and firms' reputation	13	[22,24,25,27,31-35,39,52,53,57]
5	Recognition from Third part and Implementation of EMS, TQMS	12	[20,22,24,29-31,34,39,41,46,47,53]
6	Employees	9	[25,29,31,35,38,41,42,52,57]
	Green Knowledge, Technology, Firms capabilities	9	[16,19,20,25,31,33,40,46,57]
7	Organizational values and firms desire	8	[15,18,31,40,44,46,53,58]
	Internal Policy	8	[16,17,27,28,36,40,47,59]
8	Green practices related factors	7	[20,24,25,37,47,53,57]
9	Potential liability for disposal of harmful materials	6	[16,17,22,32,41,59]
10	Innovation	5	[31,34,39,43,47]

11	Competitive advantage	4	[18,31,55,59]
	Policy Entrepreneurs	4	[18,22,41,59]
	Owners / Shareholders	4	[22,31,52,59]
	Organisational Risk Management	4	[14,18,22,53]
	Corporate strategy	4	[14,31,37,40]
12	Performance improvement	3	[33,41,59]
13	Quality improvement	2	[47,59]

Table 3 External drivers that affect GSCM implementation investigated in previous researches

Rank	External Drivers	Number of citations	AUTHORS
1	Foreign and Local Customer (Including Export, Environmental collaboration with Customer, Customer awareness)	34	[8,14-22,24,25,27,30-33,35,37,39-41,43,44,46,47,52-59]
2	Regulation (Including Government, Local, National and International, Importers regulation, Products potentially conflict with laws)	33	[8,15-22,24,25,27,30-37,39-41,39-41,43,46,47,52-55,57-59]
3	Society, NGOs and Media	20	[14,18,22,25,28,31-33,35,37,38,41-43,46,52-54,58,59]
4	Competitors	19	[15,16,21,22,25,27,30,32,33,37-39,41-43,47,52,53,59]
5	Suppliers related factors (Collaboration with supplier, Certification of suppliers and characteristics)	16	[14-17,20,22,24,25,31,35,37,39,41,43,46,59]
6	Investors	7	[14,31,41,52-54,59]
7	Internationalization	4	[8,22,31,53]
8	Global Climate Pressure	1	[52]
	Industry orientation	1	[22]

However, the implementation of Green Supply Chain Management Practices is also affected by several barriers. In contrast to the drivers, they could be defined as forces that hold up the effective implementation of green practices [41]. Similarly, they are classified into internal and external [18,23,26,27,29,32,41,45-51] as for example, the formers are the lack of senior, middle managers and employees' awareness and commitment, employee's resistance, organizational structure, lack of financial resources (costs of implementation), lack of know-how, lack of training, etc. Furthermore, the latter comes from the firm's external environment such as, the lack of government regulation, unwillingness of information trade between the firm and its suppliers, lack of consumers awareness, competition, lack of supplier's commitment and awareness, etc.

Hence, the following tables: Table 4 and Table 5, summarize, classify and rank the barriers of GSCM implementation.

Table 4 Internal Barriers that affect GSCM implementation investigated in previous researches

Rank	Internal Barriers	Number of citations	Authors
1	Financial and cost related factors (cost of implementation)	14	[23,24,26-29,32,41,45,47-51]
2	Lack of resources (Human and financial)	13	[18,23,24,26,28,29,32,41,45,48-51]
3	Lack of Top Management Commitment	10	[24,26,29,32,41,45,48-51]
4	Organizational Culture and CSR adoption	9	[24,26,28,29,32,41,45,49,51]
5	Lack of knowledge and green technology adoption	7	[24,26,28,32,41,45,48]
6	Lack of integration of IT system	6	[24,29,32,41,45,49]
7	Competitiveness related factors (Price)	4	[23,24,41,45]
	Lack of Green practices adoption	4	[24,29,45,48]
8	Difficulties in identifying and measuring costs/benefits	3	[27,48,50]
	Difficulties in identifying Environmental Performance Metrics	3	[29,48,50]
9	Employees Resistance	2	[18,29]
	Complexity of design to reuse/recycle used products	2	[48,50]
	Fear of Failure	2	[29,48]
10	Lack of Certification	1	[24]
	Strategic planning	1	[29]
	Complexity in identifying 3rd parties to recollect used products	1	[48]
	Lack of sustainability Internal audits	1	[32]
	Lack of legitimacy (compliance)	1	[18]

Table 5 External Barriers that affect GSCM implementation investigated in previous researches

Rank	External Barriers	Number of citations	Authors
1	Regulatory related factor (Government, Government fiscal incentive, International trade association)	14	[18,23,24,26,28,29,32,41,45,47-51]
	Supplier related factors (Flexibility to change, unawareness, Certifications, Lack of green suppliers, Price, Integration, Source of eco-friendly materials, No proper rewarding system to suppliers)	14	[18,23,24,26,27,29,32,41,45,47-51]
2	Customer related factors (lack of Customer demand, Unawareness, Lack of pressure, Price)	12	[23,24,26,27,29,32,41,45,48-51]
3	Industry	3	[18,28,41]
	Lack of Societal pressure and awareness	3	[32,41,49]
4	Corruption	2	[28,32]
	Lack of bank encouragement (Loans)	2	[48,49]
	Lack of Green System exposure for professionals	2	[24,48]
	Competition and market uncertainty	2	[24,49]
5	Global Financial Crisis	1	[29]
	Innovation and scientific research	1	[49]
	Internal and intermodal transport	1	[49]
	Lack of promotion of green materials in local markets	1	[51]

5 Findings and discussion

A total of 60 factors that englobe 28 drivers, and 32 barriers in total were identified from the selected literature. In this literature review only the highest weightage factors are discussed.

The identified factors were categorized and classified into, external and internal drivers and barriers, as the following:

The internal drivers that affect GSCM implementation among different contexts and industries are shown in Table 2 and ranked based on their occurrence on the previous investigated studies.

From the analysis, the common internal drivers in different industries are: Financial and Cost related factors, CSR and Company environmental mission, Top Management Support Commitment and Leadership, Green image and firm's reputation, Recognition from Third part and Implementation of EMS, TQMS seem to have the most significant weightage among the identified internal drivers.

As noted earlier, Financial and cost related factors play an important role in the implementation of GSCM practices, that could be explained by the fact that the implementation of GSCM leads to costs reduction by minimizing resources and waste, which follows the main goal of companies which is to generate higher profits and to reduce costs so as to create a competitive advantage.

Moreover, the Corporate Social Responsibility (CSR) and firms' environmental mission, occur to be the second important driver for GSCM implementation, which is represented by the firm's willingness to adopt environmentally practices within their supply chain to satisfy their stakeholders so as to enhance the corporate image.

Additionally, the Top Management Support, Commitment and Leadership play initially a significant role in the implementation of green strategies overall the firms' activities, according to Kamolkittiwong and Phruksaphanrat [37], it is explained by the role occupied by the top management inside the organization, such as, defining the firm's mission, orientation and its organizational policy.

Finally, The Green and Firm's Reputation, Recognition from a Third part are also considered as critical drivers for firms to adopt and implement GSCM. The fact that firms tend to develop green strategies to satisfy their stakeholders and to comply with environmental standards so as to generate a competitive advantage.

According to Table 3, the most weighted external drivers are the following: Foreign and Local Customer (Including Export, Environmental collaboration with Customer, Customer awareness), Regulatory related factors (Including Government, Local, National and International, Importer's regulation, Products potentially conflict with laws), Society, NGO's and Media, Competitors and Supplier related factors (Collaboration with supplier, Certification of suppliers and characteristics).

Primary, Customer related factors are the highest weightage among others, with 34 citations, this could be explained by the customer awareness that pushes industries to adopt and implement GSCM practices.

In the second range occurs the Regulatory related factors. Government and international legislation play an important role as a key force that drives firms to adopt green strategies. Thus, firms implement GSCM practices in order to avoid fines and penalties so as to comply with environmental regulation.

Moreover, Society, NGO's and Media make a major contribution as a driver that push firms to adopt GSCM practices. Society awareness has increased in the last decades due to the environmental issues that we are facing nowadays, according to Zhang et al. [42] the public pressure pushes the firms to produce environmentally friendly products and also to adopt environmentally friendly operations.

Finally, Competitors and suppliers related factors, contribute significantly to the implementation of GSCM. The following is explained through supplier's cooperation in the realization of environmentally friendly products, services, to the customer. At the same time, Firms all around the globe are continuously trying to create new and innovative ways to improve their competitiveness, thus adopting GSCM practice in order to meet environmental standards, customer demand and enhancing firm's environmental performance may lead to create a competitive advantage [42].

Based on Table 4, the most significant internal barriers appear to be the following: Financial and Cost related factors (Cost of implementation), Lack of resources (Human and financial), Lack of Top Management Commitment, Organizational Culture and CSR adoption.

As mentioned in the results, Financial and Cost related factors have the highest weightage compared to others. The implementation of GSCM practices requires high investments and generates higher costs which hinder firms to adopt such practices and comply with the environmental standards.

Along with the same line, the lack of human and financial resources hinders firms from the adoption of GSCM practices, which is explained by the fact that Human and Financial resources are an important key for firms to adopt new and innovative ways to enhance their performance and competitiveness.

Furthermore, the lack of Top Management Commitment acts also as a barrier for the adoption of GSCM practices as it is discussed above, top managers play a leading role in defining firm's orientation, mission, and organizational policy. Thus, according to Kamolkittiwong and Phruksaphanrat [37] the lack of Top Management Commitment signifies that the implementation of GSCM practices is hard to achieve.

In addition, the lack of CSR adoption and poor organizational culture obstruct the implementation of GSCM practices, that could be explained by firm's unwillingness to adopt green practice, as well by the lack of support of top management in incorporating green culture in the organization.

Besides the identified internal barriers shown in Table 4, Table 5 identifies the external barriers as follow: Regulatory related factors (Government, Government fiscal incentive, International trade association, etc.) Supplier related factors (Flexibility to change, unawareness, Certifications, Lack of green suppliers, Price, Integration, Source of eco-friendly materials, No proper rewarding system to suppliers), Customer related factors (lack of Customer demand, Unawareness, Lack of pressure, Price).

In this regard, Regulatory related factors have the highest weightage compared to other barriers. As mentioned earlier, regulatory related factors play a central role in the adoption of GSCM practices but sometimes the deficiency of government regulation, and fiscal incentives prevent such an implementation. Therefore, Regulatory related factors act at the same time as drivers and barriers.

In the same manner, customers are considered simultaneously as drivers and barriers to the adoption of GSCM, the lack of consumer or public unawareness, demand and unwillingness to pay higher for environmentally friendly products obstruct firms to implement such a practice.

Eventually, Suppliers act as a barrier in the adoption of GSCM practices, via, their unwillingness to change and to commit toward green and eco-friendly operations.

6 Conclusion

The present paper aims to identify, classify and rank the factors linked to the implementation of green initiatives among firms supply chain activities in different industries from the existing literature.

A successful incorporation of green initiatives within firms supply chain activities requires a complete understanding of factors that have an ability in influencing the GSCM adoption. Therefore, decision makers must be conscious of vital elements influencing such an implementation [26]. Consequently, an essay has been done to review the extant literature on the drivers and barriers of GSCM implementation in different industries and contexts. As result, a total of 60 elements that englobe 28 drivers, and 32 barriers were identified, classified all together into two categories such as internal and external, in which Financial and Cost related factors, Customers and Regulatory related factors seemed to behave simultaneously in both directions.

In addition to its contribution to the literature of GSCM implementation. This research might be helpful to industries that are seeking to convert their traditional supply chain and fulfil with environmental standards.

However, this study has certain limitations that might be transformed into further possibilities for future research. Particularly, a systematic literature review and an empirical evaluation of the most influencing factors in GSCM implementation has not been considered in this research. Therefore, future research might be conducted in this area. Moreover, this study will be extended into an investigation of GSCM successful implementation and firms' performance.

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POSSIBILITIES OF USING AUGMENTED REALITY IN WAREHOUSE MANAGEMENT: A STUDY

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Keywords: warehouse management, augmented reality, Pick-by-Vision system, smart glasses
Abstract: The presented manuscript points to the possibilities of implementing Smart glasses in warehouse management. With the introduction of augmented reality (AR), it is possible to speed up warehouse employees' processes must ensure significantly. The first part of the article deals with the issue of augmented reality and the object sensing system. The second part is focused on the possibilities of AR in warehouse management to increase productivity. The main part of the study focuses on comparing four systems that operate in distribution centres. The study evaluated and described the benefits of their implementation. Overall, the findings show that the performance of Smart technologies focusing on augmented reality is becoming a novelty in warehousing with significant services for businesses. AR is also pointed out by implementing Industry 4.0 ideas in the concept of creating digital twins of manufacturing companies, which is a current trend.

1 Introduction

The time we live in is technologically advanced and offers us new challenges. Augmented reality as a form of perception of the environment is its result. It provides us with a worldview that enriches us to create added value for society. Currently, the display of reality with added objects is very popular and trendy. Therefore, this article's main purpose is to analyse the use of augmented reality in warehousing as a tool to facilitate the activities of employees in a human-warehouse relationship. Perception of augmented reality we can say that we use a mobile display unit to display 3D models and information. A mobile phone, tablet and smart glasses can serve as our unit.

Division according to AR display

The technology we use to display augmented reality includes:

- Imaging device - we consider it a camera or a camera that captures the real environment.
- Computing devices — smartphones, tablets, computers, and other similar devices that perform software operations.
- Imaging device - its task is to draw the resulting image. These are devices such as a monitor, projector, HMD glasses, smartphone or tablet.

AR's accessibility to the general public is the result of an advanced time that has given us such devices that can operate easily and contain all three components working synchronously and together. Tracking, tracking or in full translation capture is the process of recognising, scanning, segmenting and analysing the environment performed using a camera and various sensors (GPS sensor, accelerometer, gyroscope, digital compass, etc.) [1].

The blog blippAR.com writes that augmented reality can be divided into three basic methods according to how digital objects are displayed. Let's look at the options we know to start displaying digital content [2].

1.1 Marked- Based AR

Marker-based AR or augmented reality based on markers is a typical way that real-time object tracking can work. The marker is the starting point and characteristic of this method. It can be characters, pictures, and real objects, whose main task is to carry digital information. The technology uses a marker to recognise the position, orientation of an element in space, or other properties that describe an object. Subsequently, using the software makes it possible to turn the marker into a digital item using AR. Markers also developed, which led to the fact that any image, even a living element of the physical world, could be considered a marker. Bar codes and later QR codes are considered among the first markers. Clear development and division of markers into groups was prepared by Professor Vladimir Geroimenko and shown in the following diagram in Figure 1 [3].

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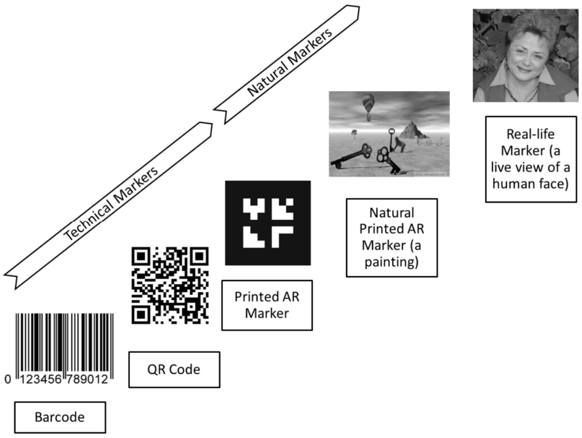

Figure 1 Development of markers according to V. Geroimenko [3]

To better understand the use of marker-based AR, we can give an example with animation in a book: If we want to display an educational application in a book, the user must have a device with appropriate software and a camera. The user must recognise this marker on the relevant side, where a distinctive image serves as a marker, and point the device's camera at it. Subsequently, a digital visualisation will be displayed, i.e. an animation hidden in the appropriate tag. The user can also move through the physical book and see how the virtual object "holds" on the page's actual surface [2].

1.2 Markerless - Based AR

As the name implies, we can deduce that markerless AR applications do not use markers to recognise and mediate augmented reality. This augmented reality method does not require prior knowledge of the user environment for the 3D content to occur and be held in a fixed place in space. It is a method where the user can move entire virtual objects in a real environment. We will also give an example to clarify this way of displaying AR: Imagine an application that can help us furnish an apartment's interior. The application must be available on a device with a camera; the most commonly used are smartphones or tablets. Subsequently, the user must decide where to insert the virtual object (in our case furniture), and the camera captures the space. The table does not float when stored in the area; we can anchor it on a flat surface for a realistic idea. Many such markerless AR applications are more accessible to the general public, especially on smartphones.

1.3 Location - Based AR

This kind of augmented reality does not need markers to track. Position recognition is important. Spatial orientation is performed using GPS coordinates, electronic gyroscope or compass. Location-based AR is more suitable especially for the exterior. A device using this AR method knows with sufficient accuracy where it is located or rotated. As with the previous types, it is better to understand AR's workings with an example: Imagine we are walking down an urban street. We see a landmark we would like to know more about. A device with the appropriate location-based AR application registers a virtual tag with the camera. It will then display information about the object. However, to ensure that digital AR content appears in the right place, your device must pinpoint its location. The Pokemon GO application is also known for this way of displaying AR [4].

Division according to the use of the senses

Defining the division of AR according to the senses is shown in Figure 2, which depicts all kinds of reasons that a person can perceive and the corresponding kind of augmented reality.

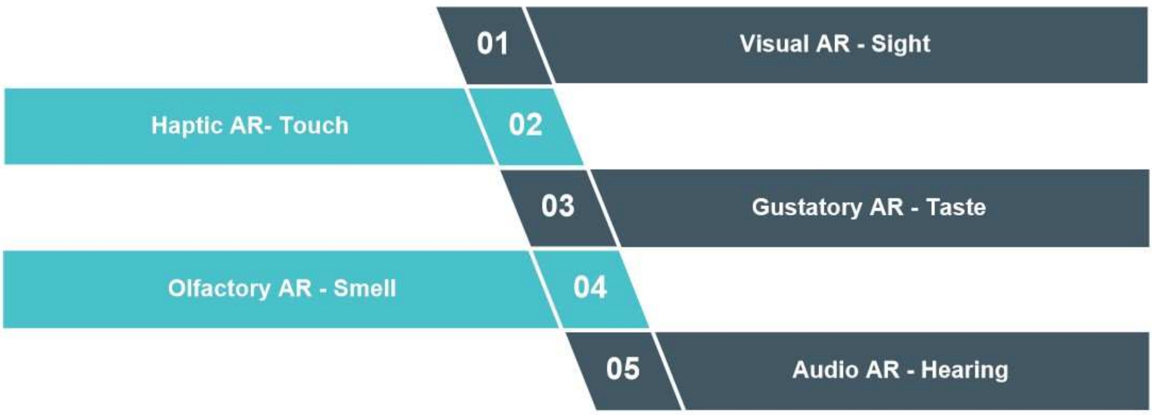

Figure 2 Augmented Reality divided according to senses [5]

- **Visual AR** - Most of the information a person has visually acquired. AR enhances the visual sense and allows people to see the digital and physical worlds simultaneously. It is the most common way of administering AR, applicable almost everywhere.
- **Audio AR** - Audio-transmitted AR mainly uses glasses and headsets to, e.g. the workers had their

hands free and could operate the handling equipment. The kit has the attenuating effects of external background noise and can provide product information at work.

- **Haptic AR** - This AR is based on tactile sensors and their feedback. It can play an important role in medicine by using 5G haptic gloves in remote surgery and teaching doctors in large numbers through real-time professional cooperation.
- **Olfactory AR, Gustatory AR** - Smell and taste are theoretically also usable in augmented reality, but at the moment they are just thoughts of the future. It is assumed that these types of AR could sensory identify the threat in the company. According to the blog of the ericsson.com portal, they are more likely to be used in the gaming industry, to improve the enjoyment and enjoyment of the game [5].

Division according to the way the image is joined

There are three different ways to combine a physical environment image and a virtual environment image. We know the so-called "See-through AR" (optical and video display) and "Spatial AR" (PA model) [6].

OPTICAL SEE-THROUGH

This optical display method uses normal or semi-transparent mirrors to display the real environment. The virtual object is implemented in these mirrors, and thus the real and digital world and its combination are connected. It belongs to the older ways of clicking the image, today we already know much more advanced methods.

VIDEO SEE-THROUGH

A well-known system using a camera for recording the surroundings, where the connection and display of the relationship between the digital and real image on the display is performed utilising a computing device (e.g. smartphone, tablet). The great advantage of this system is the possibility of interaction with augmented reality.

Projection augmented models (PA Model)

Spatial AR is a type of augmented reality where computer-generated information is projected directly into the user environment. The PA model belongs to this AR-type and is closely related to the tactile user environment (TUI). TUI was developed by Hiroshi Ishii, a professor at MIT Media Laboratory, who presents tangible bits as a vision that seeks to give a physical form of digital information. The bits can then be directly manipulated and tactile, thus seeking a seamless connection between physical and virtual objects [7].

The PA model can be understood as imaging using a projector, where the object can be projected directly into the real environment on a wall, objects or as a hologram. According to Di Donat, when casting on a wall or on objects, it is not always necessary to speak of AR, but this is quite certain [8].

2 Methodology

Picking goods is one of the most important phases and operations in the warehouse, where proper warehouse logistics can save the company considerable financial costs. This initial phase of fulfilling a customer order is most important, as it is essential for the functionality of other processes such as order packaging, shipping, and after-sales activities. Besides, this basic warehousing process covers the highest part of the warehouse's operating costs and expenses. Therefore, the selection of goods from the warehouse, respectively. Picking must be flawless, and automated systems and technology are also needed to streamline the whole process. In this area, augmented reality is engaged and implemented as a management tool for picking goods.

To streamline and speed up the entire order picking process, employees are looking for ever newer solutions through new technologies and picking systems [9]:

- The Pick-by-Paper system is a traditional way for employees to remove goods from the warehouse. In their work, they use a paper list of goods, which contains the number of goods, the number of required pieces and the location in which the assortment is located. Working with such a system is inefficient and very laborious.
- The RF picking system is a very popular picking system, where all products must be marked with RFID codes. Using radiofrequency mobile devices - terminals, the appropriate RFID code is scanned from the tag, and then the action is performed. RFID scanning can be easily disturbed by the close presence of some devices, amounts of fluids or metals.
- The Pick-by-Light system is more difficult to install, as you need barcode scanners and special LEDs located directly on the shelves and racks of the warehouse, so this system is costly.
- The Pick-by-Voice system is another way to help an employee and streamline their work in selecting and picking goods through a headset that provides him with an input flow of information and instructions. This system's disadvantage is the impossibility of use in a noisy environment because the employee would not hear instructions from the system.
- Pick-by-Vision system

It is the Pick-by-Vision system that will interest us from the perspective of augmented reality. It is one of the most modern techniques for the order picking process and differs significantly from the systems mentioned above. The interest of this system supported by augmented reality is navigation based mainly on visualisation, which can be divided into 3 types, which are mutually supported [10]:

- Meta navigation- Draws the user's attention to objects that are out of the HMD's field of view at a particular time.
- Rough navigation - The goal is to transport the user to the correct aisle and shelf of the warehouse.

- Fine navigation - From it, the user has the best experience of augmented reality, because the system navigates him directly to the field he needs. Subsequently, he can pick up the goods from the found box.

With augmented reality, Vision picking has created a completely new way of managing warehouses and has made it possible for many companies to streamline their accuracy and productivity level. This relatively new technology advances warehouse management by saving manual effort, time, and eliminating individual errors. There are development companies on the market. There are currently systems from Knapp, SAP, DHL and Ubimax creating an extended environment using HMD for the pick-by-vision system, from which large companies can choose to address them [11].

3 Results and Discussion

In terms of sales and logistics, the two areas are closely linked. The importance of logistics for total sales lies in the speed and efficiency of the delivery of goods in a warehouse-customer relationship. This section will look at how the logistics process has changed and how AR technology is implemented in this area.

In recent years, the entire logistics process has been technologically improved by transforming and digitising various processes, resulting in Logistics 4.0. [12]. Technological improvements can also be seen in the introduction of advanced computer vision techniques, such as augmented reality. It can influence and streamline key processes in the warehouse, such as collecting, sorting, and loading goods. This technology makes the warehouse smarter by making it easier for operators to pick goods, show them the right way to sort the range, help operators load goods in the best possible order, and identify and alert the risk of damage when distributing goods [13]. All this is done with IoT, which helps us connect devices, objects and people to the Internet. In warehouses, this will provide much faster access to data and information. There are many possibilities for using augmented reality in the logistics system, but the most common is vision picking. As mentioned above, pick by vision is mediated by an HMD display, i.e. smart glasses of various brands. This article focuses on vision picking, which describes in detail the use of pick-by-vision by DHL, which has long been involved in developing this innovation and, in addition to annual reports, also provided an expert study on this topic. We also know other companies in the world known for implementing such tools to support and streamline the entire logistics process [14].

3.1 *Vision picking by DHL*

DHL's global supply chain is one of the first companies to introduce augmented reality technology into the Vision Picking program. In cooperation with Google, Vuzix and Ubimax, it was first tested in 2014 at the Dutch DHL plant. The entire system runs on a platform from Ubimax, where a worker uses Google Glass or Vuzix smart glasses and a ring scanner to pick up goods. These devices provide the operator with several functions and information. The first step for working with the system is to log in the operator and turn on the necessary equipment. After being greeted by the device, the user selects an available cart to pick and scans it into the machine. A visual aid is graphically displayed through the glasses, where you will find the information needed to pick up the order. The user sees the aisle number in the graphical tool, the exact allocation of the goods, the quantity he has to select, and the next item. This information accurately, quickly and efficiently guides the worker to a given order item. Therefore, this method of picking goods is much more efficient than the classic paper form of picking. After reading the item's barcode with glasses, the system automatically indicates in which of the boxes on the cart the item should be inserted and in what number. The system knows exactly the position of the boxes on the trolley. By using the headset, the worker's hands are released, so he can work more efficiently. The visual aid in the glasses helps sort the products (Figure 3), thus ensuring the speed and overall quality of work. Regarding training workers and comprehensive integration into the work process, we can say that this technology is not difficult to use and will be quickly adopted by the worker. DHL's vision is to integrate AR into the entire process of distributing goods in the warehouse across multiple operations to increase and improve customer benefits [15].

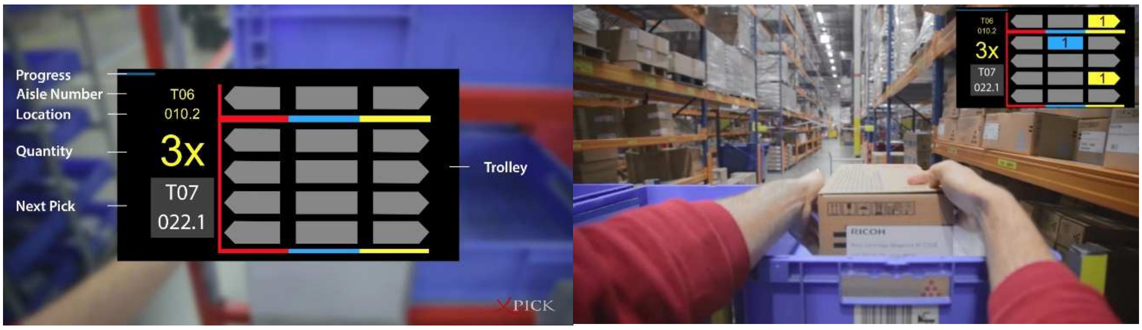

Figure 3 DHL Vision Picking [15]

DHL is considered to be one of the first companies to address the topic of augmented reality through pick-by-vision in logistics. However, we also know other world giants in their field who have also started picking goods using this technology because they saw potential. All the companies use xPick from Ubimax for picking goods, as well as DHL, xPick. This augmented reality solutions company is among the best in its field. Because all selected companies use xPick, the way the software works and works is very similar.

3.2 Samsung SDS

SAMSUNG SDS is a subsidiary of Samsung Corporation, which develops and researches new information technologies such as IoT, AI, Blockchain and the like. As part of the Samsung Cello project, they introduced vision picking in 2015 and incorporated it into their intelligent storage program at a European distribution centre in the Netherlands. The entire technology runs on the Ubimax platform. After switching on the device, the user starts picking the goods by finding the goods' position using smart glasses. Employee checks (Figure 4) the number of the selected goods if everything fits, he confirms it with a smartwatch and enters the number. The employee continues by checking the other goods with glasses and going over them. The visual aid mediated by the glasses provides information to a similar extent as in the DHL system [16].

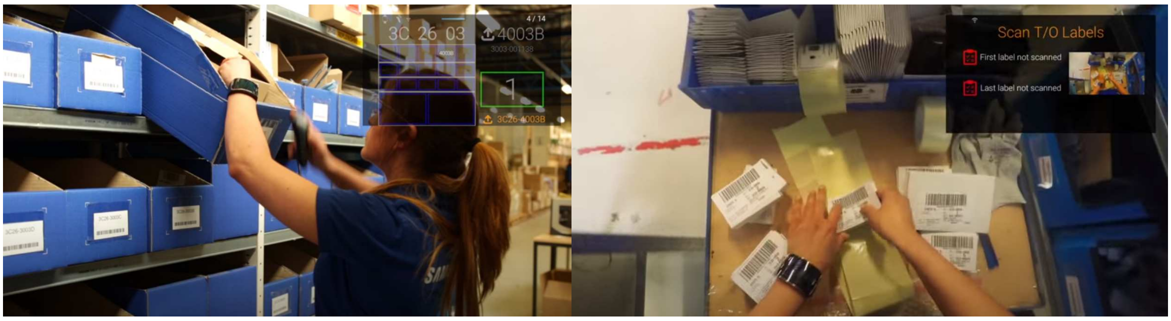

Figure 4 Samsung Vision Picking [16]

3.3 Coca-Cola HBC

Coca-Cola HBC is a company based in Thessaloniki, Greece, known to everyone as a beverage company. The difference between the method of picking goods in this company and the previous two is using the device. In northern Greece, in 2019, they began this method of picking through the RealWear HMT-1, which have a more powerful appearance than Google Glass. In the virtual image in the field of view, the worker sees the picked objects, picking points and quantities. He gives instructions by voice and confirms the process. The hands-free set also includes a camera, with which the worker reads the QR code of the pallet needed when picking the goods. They combined this innovation with the Coca-Cola SAP and WMS production system for fast real-time information flow [17].

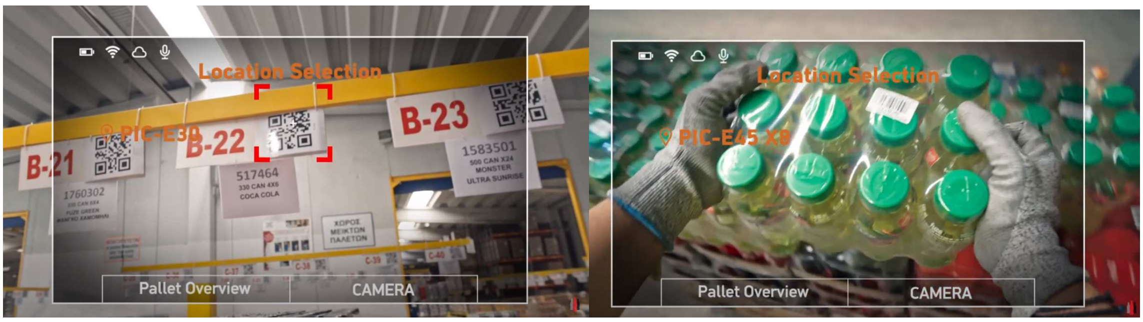

Figure 5 Coca – Cola HBC [17]

3.4 Intel ADC

The Intel distribution centre in Arizona tested vision picking in 2017. The xPick software was supplemented by Intel Recon Jet Pro glasses developed specifically for their distribution centre. These glasses are designed to fit ergonomically in a given work environment. The information about the goods is graphically displayed in the glasses. In the upper right corner, the worker sees the aisle and shelf position where the goods are located. The left part of the field of view is the remaining information, such as the product code, the number of goods and the next item. When picking up the product, a Zebra ring scanner is also used, which scans individual objects' barcodes. The system automatically notifies the employee to document (Figure 6) the delivery note before proceeding to the next order [18,19].

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Figure 6 Intel ADC Pilot [18]

Table 1 shows the technologies used by selected companies when picking goods in a pick-by-vision manner for better clarity.

Table 1 Equipment used by selected companies for Vision Picking [authors own processing]

DHL Supply Chain	SAMSUNG SDS	COCA-COLA HBC	INTEL ADC
Google Glass ENTERPRISE EDITION VUZIX M100 VUZIX M300XL ZEBRA scanner	Google Glass ENTERPRISE EDITION SOCKET mobile scanner Samsung Gear S2	RealWear HMT-1	Intel Recon Jet Pro ZEBRA scanner

Conclusion

Each of the analysed companies using vision picking for the distribution of goods praises the technology over time and sees great benefits. In the following points, the benefits brought by augmented reality technology for the support of warehouse logistics are subjectively evaluated:

- improving ergonomics at work
- increased safety by releasing the hands
- faster picking
- amount of information in one device
- connection to the entire warehouse system and response speed
- no rugged scanners and papers
- ease of use
- clarity of information about the goods in the facility
- speed of training
- use even in noisy environments
- eliminates the risk of causing an error to personnel
- change in the work environment and the absorption effect on the worker

These benefits are reflected in the overall increase in productivity. The error rate will be reduced many times with the introduction of vision picking.

Accuracy is very important for customer satisfaction. In the following Table 2, we can see how the use of augmented reality in selected companies has contributed.

DHL Supply Chain	SAMSUNG SDS	COCA-COLA HBC	INTEL ADC
Productivity increase by 15% speed increase by 25%	Productivity increase by 12-22%	Increase performance by 6-8%	Speed increase by 29%
Increased accuracy	Reduction of error rate by 10%	Accuracy 99,9%	Error rate 0%

Table 2 Equipment used by selected companies for Vision Picking [authors own processing]

The analysis of the way of using augmented reality in picking goods brings added value in two points - the share of the use of augmented reality in the logistics of global companies and a description of the benefits of the technology based on research activities of these companies. It is known that more than half of the resources in the warehouse are involved in order picking work, and therefore major global companies are trying to reduce these costs. One of the innovative tools is the vision picking just researched. Selected companies (DHL Supply Chain, Samsung SDS, Coca-Cola GBC, Intel ADC) adopted this method in their operations in 2014-2020, but all these companies had uniform conclusions. Implementing augmented reality through smart glasses with appropriate software reduces errors and the risk of injury at work. On the contrary, it increases the accuracy, performance, speed and flexibility of the worker, which bears fruit in higher overall productivity. From the point of view of this issue, we conclude that medium and large companies' attractiveness and potential is very great. This new technology investment could be costly and unnecessary for small businesses due to the smaller number of products. We assume that vision picking will, thanks to its benefits, become an increasingly popular option for distributing goods to customers, and many new warehouses and distribution centres will adopt this technology. Smart glasses allow employees to work ergonomically and more efficiently to work hands-free and without work administration. However, these glasses have limited endurance, so manufacturers' challenge is to increase this battery capacity constantly. We are concerned that working with headsets for a long time may result in poor vision and headaches. But compared to traditional paper picking or popular barcodes and RFID scanners, this method is a much more efficient solution.

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MODELLING OF FINANCIAL RESOURCE ALLOCATION FOR INCREASING THE SUPPLY CHAIN RESILIENCE USING MARKOV CHAINS

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Keywords: supply chain resilience, resource allocation, modelling, Markov chains
Abstract: The concept of supply chain resilience has arisen in response to changing conditions in the global market environment. Although supply chain resilience building is gaining increasing interest among the professional public and business practice, supporting decision-making in supply chain resilience building is still in its infancy. This article aims to present a mathematical model of the supply chain based on Markov chains to assess the impact of funds allocated to strengthening the supply chain's resilience to its overall performance and thus support decision-making in the field. Mathematical model assumptions are presented, then a mathematical model of a linear supply chain is developed and generalized, tested and methodological recommendations are presented. To support the use of the model, a set of managerial implications is presented, benefits and limitations are discussed, and further research direction is defined.

1 Introduction

The current market environment, which its ever-increasing complexity and globalization can characterize, is invariably subject to heightened instability and sudden changes. The environment thus becomes turbulent and leads to gradually increasing demands on management processes. This leads to an increased emphasis on logistical management and optimization in the broadest possible interpretation of these notions across the whole supply chain. It is no longer possible to only optimize processes inside a managed company, but it is also important to look beyond the boundaries of the company, towards its suppliers and customers, and assess company management from the viewpoint of its incorporation into a complex system of interconnected entities. One of the latest concepts reacting to these needs is the notion of the resilience of supply chains. The contemporary importance of supply chain resilience is also confirmed by the BCI Supply Chain Resilience Report 2018 [1] of the Business Continuity Institute. The motivation for the submitted research work is to help answer questions arising in the area of the strategic management of supply chains, and specifically related to building up their resilience: "Which parts of an industrial supply chain should receive financial resources in order to increase resilience and how many financial resources should be allocated for this purpose in order to maximize the resulting economic impact?" The aim is to lay the foundations for a mathematical model based on Markov chains which will facilitate the comparison of the impacts of different allocations of financial resources onto increasing the resilience of individual parts of the supply chain.

2 Supply chain resilience and disruptions

The notion of resilience focuses on the requirement that supply chains should be able to withstand changes in a turbulent, unstable environment and building up resilience is based on a perception of changes in a business environment and disruption risks. These risks may be divided into several basic categories, notably including internal risks and external risks for the company and external risks for the supply chain [2]. The central principle for the building up of resilience is the reduction or removal of the vulnerability of supply chains towards possible disruptions; this is naturally based on a concrete understanding of such risks. Resilience is then understood as the ability of a supply chain to return to its original condition after an unexpected disruption [3].

Disruption of a supply chain is defined as a reduction of its output, or a complete breakdown of its elements or the supply chain as a whole, as a consequence of an internal or external event. Based on the World Economic Forum [4], we may define five primary sources of disruptions: natural disasters, extreme weather, political conflicts and problems, terrorism, and sudden radical changes in demand.

Building up resilience is a strategic goal that requires active collaboration between all involved parts of the chain and the exertion of substantial financial resources. Resilience is built up by improving the capabilities of the supply chain, which notably include the flexibility of obtaining resources or handling of orders, capacity, efficiency, visibility, adaptability, prediction, restoration, dispersion, collaboration, organization, market strength, security and financial strength [5]. Currently, the capabilities required for building up the resilience of supply chains have been studied by a number of authors, often presenting significant differences in their interpretation of how these capabilities can be improved [6-11].

3 Supply chain resilience modelling

Ribeiro and Barbosa-Povoa [12] summarized contemporary quantitative approaches used to model the resilience of supply chains in their study from 2018, in which they analyzed nearly 40 recent scientific publications and presented a survey of this area. The authors emphasized the importance of finding an unambiguous definition of resilience and focusing future research on the development of quantitative methods for evaluating and building up resilience from a global perspective rather than assessing the individual components of supply chains.

There is a range of specialized studies that focus on modelling supply chain disruptions, especially from the area of operations research and management. Here we can mention, for instance, the exhaustive study of Snyder et al. [13], which surveys the state of the area. Based on the analyzed articles, the authors list several fundamental findings and recommendations for future research in this area:

- Rejection of risk – most models primarily focus on disruptions that occur infrequently, and decision-making is expected to be carried out from a neutral position. In practice, this may lead to the rejection of risks and a focus on optimizing non-key parameters.
- Estimation of input parameters – historical data on disruptions of supply chains are very rare, and an estimation of the input parameters is hence very complex. Most models, however, use the assumption that parameters can be determined or estimated with high confidence. One of the main directions for future research should thus be the development of techniques for the reliable estimation of the parameters of disruptions or models which work well without such data.
- Proactive and reactive strategies – a large portion of the introduced models focus on finding an optimal strategy for dealing with disruptions. Most models consider either proactive measures or a reactive strategy that can be used once a disruption is identified. Future research should also focus on models that can simultaneously support both of these responses.

The approaches for modelling resilience are prominently shaped by the simulation introduced by Grakova [14] in her PhD thesis. There, she defines the basic steps that need to be taken in order to efficiently use simulation software for identifying key elements of a supply chain and comparing various schemes for allocating financial resources in order to increase the resilience of a supply chain. The work follows up on preceding research that attempted to simulate the behaviour of supply chains, situated primarily in the area of risk management for supply chains.

Another simulation study has been authored by Falasca et al. [9], who define three basic factors that impact the resilience of a supply chain – its structure, complexity and the criticality of individual elements – and propose a methodology for creating simulation models and scenarios of simulation experiments. Carvalho et al. [15] introduce a simulation model for a supply chain that evaluates the supply time and overall costs as the basic output parameters used to assess the resilience of a supply chain in the automotive area. Nunes et al. [16] expand the previous model with an application of fuzzy set theory and analyze the impact of supply chain disruptions and of the measures adopted to reduce the impacts of such disruptions.

4 Research gap identification

Our current understanding of the area of supply chain resilience clearly indicates that up to now, research primarily focused on finding a definition of resilience and a subsequent evaluation of the amount of resilience of a supply chain. As far as building up resilience is concerned, the studies carried out to date consider mostly general and qualitative recommendations for resilience built-up, while the actual measurement of resilience is still in its infancy – there is no unified methodology for such measurements, and in general, the topic has not attracted much attention among scientists in the field. This means that the management of industrial supply chains can receive qualified recommendations about, e.g., which key skills of the supply chain they should focus on and what to aim for when trying to improve these. However, the possibilities for supporting decision-making processes in the area of allocating funding for resilience build-up have not been covered by research to date; this fact has also been noted by Rice [17].

One of the prominent advances in the area of decision-making support for resilience build-up in view of the efficient utilization of financial resources is attributed to Grakova [18], whose PhD thesis focused on the use of simulations. A prerequisite for her approach is a sufficient understanding of the selected simulation tool. Another disadvantage of the simulation approach is the relatively high time requirement: in order to evaluate the carried-out experiments, it is necessary to carry out a statistically sufficient number of independent experiments, and moreover, it is not possible to simulate too many schemes for financial resource allocation. In view of these facts, Grakova proposed the use of experiments designed based on DOE (Design of Experiments) principles. On the other

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hand, the use of DOE significantly restricts the number of parts that can be included in the simulated supply chain.
The aim of this article is to build on state of art in the area of supply chain resilience build-up and introduce a mathematical model that allows us to answer the question of which part of a supply chain should receive financial resources in order to increase the chain's resilience so that the economic impact of such an investment is maximized to ensure the efficient use of the financial resources. The introduction of the mathematical model opens up new possibilities for building up the resilience of supply chains precisely in this area.

5 Modelling of stochastic systems using Markov chains

A Markov Chain typically describes a discrete stochastic process with the core feature that the probability of transitioning to another state depends only on the current state and not on previous states. This property of the investigated system is called the Markov property and allows the behaviour of the studied system to be depicted as a state graph. The abstract notion of a stochastic process [19] can be used to describe random phenomena which are a function of time. Examples of stochastic processes can be found across many scientific disciplines and also in numerous real-life situations. The mathematical theory behind Markov chains used to create the mathematical model is based on literature dedicated to this topic [19-21].

For the purposes of this article, we hereinafter only consider real random variables, even though the theory of stochastic processes also analogously defines complex random processes. The modelled system is characterized as a stochastic process with a discrete notion of time and discrete states, where random variables are only assigned discrete values and where the stochastic processes range over independent values. For the purposes of this article, we hereinafter consider only homogeneous Markov chains.

6 A Model supporting decision-making when building up supply chain resilience based on Markov chains

The following paragraphs introduce a mental map of the studied problem, specify the prerequisites and define the input parameters of the mathematical model. The theory of Markov chains is then used to create a mathematical model for supply chains consisting of two chains in a supplier-consumer relationship, which is then generalized to support an arbitrary number of linearly interconnected chains.

6.1 Mental map

A supply chain is viewed as a system of series-connected entities (parts) of the chain, which assume the roles of suppliers and customers. The idea is to look at chains from a global context, where individual parts operate in distinct regions – meaning not necessarily geographically separated regions, but also, for instance, regions that are separate from an economic, political or cultural standpoint. Individual regions can be analyzed in terms of their entrepreneurial environment, and this can serve as a basis for an estimation of the nature of possible disruptions, the probabilities of their occurrence or the time required to remove the consequences of such unexpected events. The considered supply chains are capacity-neutral, and a part in a chain that follows a preceding part can process precisely the number of inputs that the preceding part produces. The maximum capacity of individual parts is reduced due to the occurrence of significant disruptions, leading to the possible loss of parts or a reduction of the capacity of individual parts until the consequences of the disruption are removed. No part of the supply chain can stockpile its output, and hence the reduced capacity will be felt immediately once disruption occurs. Next, this mental map is transformed into a set of requirements for the mathematical model.

6.2 Requirements for the mathematical model

The following subsections summarize the requirements for the mathematical model with respect to the structure and operation of the investigated supply chain and its individual parts, the properties of the considered disruptions, their impacts and possible ways of reducing said impacts. The set of requirements for the mathematical model is based on an abstraction of a supply chain and the requirements form the foundation for the mathematical model.

6.2.1 Logistical requirements

- A supply chain is a system of interconnected links linked with supplier-customer relations.
- A part of a supply chain represents a set of suppliers or customers operating in a single region.
- The supply chain is series-connected (linear).
- The supply chain is capacity-neutral. There is no stockpiling.
- The supply chain cannot be blocked by-products that are awaiting processing during a disruption.
- Disruptions occur randomly and affect individual links operating in distinct regions, whereas the mean time between disruptions and the mean duration is random variables characterized by an exponential distribution.
- All parts of a supply chain may be affected by a disruption, even simultaneously.
- It is possible to identify the Mean Time Between Failure (MTBF) and Mean Time to Recovery (MTTR) for each part of the supply chain.
- The MTBF is greater than the MTTR.
- The resilience of the supply chain, and specifically its individual parts, can be increased by allocating financial resources.

- The increased resilience of the supply chair, and specifically its individual parts, leads to a reduced MTTR, but does not affect the MTBF (in line with the adopted definition of resilience).
- It is possible to determine, for each part of the supply chain, the functional dependence of the MTTR on the number of financial resources allocated to the given part with the aim of increasing its resilience.
- The MTTR has an indirect linear dependence on the amount of allocated financial resources.
- For each part of the supply chain, it is possible to determine the minimum amount of financial resources that are required to start increasing its resilience.
- The attributes (and hence the values of input parameters) of individual parts of the supply chain are obtainable (e.g., via an expert report or from an analysis of the business environments and internal potentials of individual articles).

6.2.2 Methodological requirements

- The supply chain can be viewed as a Markov process with discrete time steps.
- The output of the supply chain can be estimated based on stationary probability distributions specified for the system at its individual designated states, calculated based on the theory of Markov processes.
- Due to the use of Markov processes with discrete time steps, the MTTR cannot be reduced beyond the value of 1 step.
- It is possible to find a solution for the task of allocating financial resources for increasing the resilience of individual parts of the supply chain that will ensure the maximum possible increase of the overall output of the supply chain after deducting the total allocated financial resources in the modelled period.
- The time dimension is implicitly included in the model as a parameter of the maximum output of the supply chain. This output is specified as an input parameter of the model and is represented via the economic performance of the supply chain over the modelled period.
- The model should be used to support strategic decision-making, whereas the modelled period refers to a time period that the given supply chain considers being of strategic importance for its operations.

6.2.3 Economic requirements

- The output of a supply chain whose resilience has not been increased (the original output) is represented by the cumulative economic output of all parts over the modelled period.
- The output of a supply chain after its resilience has been increased is represented by the cumulative economic output of all parts over the modeled period after their resilience has been increased via the allocation of financial resources.
- The increased output of a supply chain after its resilience has been increased is defined as the output of the supply chain with increased resilience minus the original output of the supply chain and additionally minus the total financial resources allocated to increasing the chain's resilience.
- Allocated financial resources represent any and all costs exerted into increasing the resilience of the supply chain.
- Disruptions lead to a relative reduction of the output of the affected part of the supply chain (e.g., to 20 % of the full output of the given part).

6.3 Creation of the Mathematical Model

Below, we define the input parameters of the mathematical model and derive a mathematical model for linearly structured supply chains with two parts in a supplier-customer relationship, which is then generalized for linear supply chains consisting of n parts ($i = 1, 2, \ldots, n$).

6.3.1 Input parameters of the mathematical model

Based on the above-mentioned mental map following input parameters of the mathematical model are defined:

- $\boldsymbol{MTBF_i}$ – Mean Time between Failures of $\boldsymbol{i}$-th link of the supply chain (days),
- $\boldsymbol{MTTR_{i,0}}$ – initial Mean Time to Recovery of $\boldsymbol{i}$-th link of the supply chain with no funds allocated to improve the links' resilience (days),
- $\boldsymbol{I_{i,\min}}$ – the minimum amount of financial allocation, which will lead to an increase in the resilience of the $\boldsymbol{i}$-th link in the supply chain (EUR),
- $\boldsymbol{I_{i,\max}}$ – the number of funds needed to fully eliminate the effects of disruption of $\boldsymbol{i}$-th link in the supply chain (EUR),
- $\boldsymbol{I_i}$ – allocation of funds to increase the resilience of the $\boldsymbol{i}$-th link in the supply chain (EUR),
- $\boldsymbol{V_{i,\mathrm{NOK}}}$ – relative performance of the $\boldsymbol{i}$-th link in the supply chain at the time of operation under disturbance (%),
- $\boldsymbol{V_{\max}}$ – maximal performance of the supply chain in a modelled period without any disturbance (EUR),
- $\boldsymbol{I_{\max}}$ – the maximum amount of the sum of all funds allocated in individual supply chain links (EUR)
- $\boldsymbol{i = 1, 2, \ldots, n}$ – the designation of the $\boldsymbol{i}$-th supply chain link, where $\boldsymbol{n}$ is the number of links of the supply chain,
- Supply chain structure defined by the directed acyclic graph.

6.3.2 A Mathematical model for a supply chain with two parts

Let a “scheme” be a specific allocation of the financial resources to individual parts of the supply chain. Then, by determining how the output increased after the resilience was increased via various schemes, it will be possible to compare these schemes and choose the best one. Here, the best scheme is one that, based on the problem setup, provides the supply chain as a whole with the best economic effect, i.e., a scheme which maximizes the difference between the supply chain’s output after applying the scheme and the supply chain’s output without any scheme minus the sum of allocated financial resources. The function we want to optimize is thus defined by the following formula (1):

$$Z_{\max} = V_{\mathrm{I}} - V_0 - \sum_{i=1}^{n} I_i \tag{1}$$

where:
V_{I} is supply chain performance after increasing the resilience via a specific scheme of allocation of available funds between individual supply chain links (EUR),
V_0 is original performance of the supply chain in a modelled period (EUR),
n is the total number of links in the supply chain,
I is $I = (I_1, I_2, \dots, I_n)$ specific distribution of financial resources between individual links in the supply chain, the so-called “scheme” (EUR),
I_i is the number of funds allocated to increase the resilience of the i-th link of the supply chain for $i = 1, \dots, n$ (EUR).

Determining the value of the optimization function requires the performance of certain calculations. The total financial resources allocated to increasing the resilience of the supply chain can be calculated as a simple sum of all resources allocated to individual parts, i.e. $\sum_{i=1}^{n} I_i$. Based on the specified requirements, the following constraint must be satisfied (2):

$$\sum_{i=1}^{n} I_i \in \langle 0; I_{\max} \rangle \tag{2}$$

where $I_{\max}$ is the maximum sum over all allocated financial resources.

In order to determine the output of the supply chain after its resilience has been increased via the allocation of financial resources amounting to I_i for individual links and its original output without any allocated financial resources, the behaviour of the considered supply chain is modelled as a Markov chain.

Below, we derive the mathematical model for a supply chain consisting of two links (see Figure 1, where “SCL” refers to individual links). This is then generalized to n links in Subsection 6.3.3.

Given the requirements specified above, the behaviour of the supply chain can be viewed as a Markov process, i.e., a sequence of random integers $\{X_\tau, \tau \in \mathbb{N}\}$ in a defined probability space (Ω, A, P). Let S be a finite set of states of the random process $\{X_{\tau-1}, \tau \in \mathbb{N}\}$ and let its elements be the states of this process. For each part of the supply chain and at each time point, there are two states that it could lie in:

- the i-th link is fully operational,
- the i-th link is disrupted.

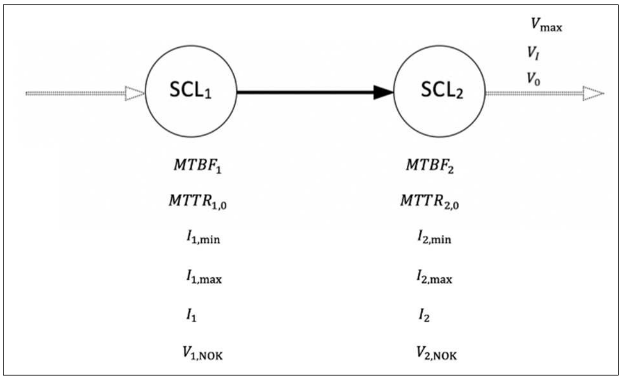

Figure 1 Scheme of a supply chain of a linear structure consisting of two supply chain links

The states of the individual parts can be identified by a binary digit, where 1 means that the i-th part is operational and 0 that it is disrupted. It is thus possible to define and label all possible states that the modelled supply chain could reach over time, see Table 1. The code for the state of the supply chain can be expressed via a binary number c consisting of $n = 2$ (where n is the number of parts of the supply chain) digits c_k, as follows (3):

$$c = \sum_{k=0}^{n-1} c_{k+1} \cdot 2^k = c_2 \cdot 2^1 + c_1 \cdot 2^0 \tag{3}$$

where:

$$c_1, \dots, c_n \in \{0,1\}.$$

Table 1 Possible supply chain states

Supply chain state	State of SCL_1	State of SCL_2	Code of supply chain state (c)	State description
0	0	0	00	Both links disrupted.
1	0	1	01	Link SCL_1 disrupted, link SCL_2 fully operational.
2	1	0	10	Link SCL_1 fully operational, link SCL_2 disrupted.
3	1	1	11	Both links fully operational.

MODELLING OF FINANCIAL RESOURCE ALLOCATION FOR INCREASING THE SUPPLY CHAIN RESILIENCE USING MARKOV CHAINS
Martin Čech; Radim Lenort

The supply chain consists of 4 states. Hence, let $S = \{0, 1, 2, 3\}$ be the set of all states of the supply chain, viewed as a Markov process. The Markov process describing the behaviour of this system can be visualized as a graph, where the nodes represent individual states and edges represent the transitions between states with the appropriate transition probabilities p_{cd}, see Figure 2.

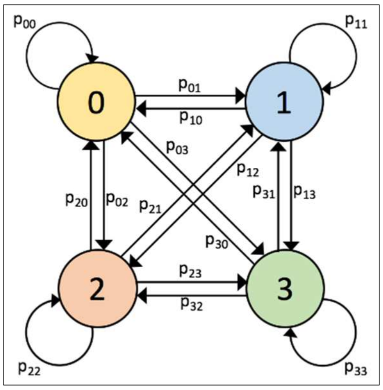

Figure 2 Graph of Markov chain of the modelled supply chain of two links

For the considered supply chain, viewed as a stochastic process and/or a homogeneous Markov chain, Markov theory states that it is possible to create a regular matrix $\boldsymbol{P}$ (4) of transition probabilities between individual states. In our case, this will be a 4×4 matrix:

$$\boldsymbol{P} = \{p_{cd}\} \tag{4}$$

where:
$c = 0, 1, 2, 3$ is initial supply chain state,
$d = 0, 1, 2, 3$ is following the supply chain state.

The following paragraphs explain the formulas for computing the probabilities p_{cd} of transitions between an initial state c and a following state d of the supply chain, and how these are obtained. In order to determine the transition probabilities p_{cd}, it is necessary to consider the probabilities of state changes for individual parts of the supply chain when their state changes.

As was described above, each part (in a specific region) of the considered and modelled supply chain exhibits a linear dependency of the MTTR (defined only within the interval $\langle I_{i,\min}; I_{i,\max}\rangle$, where $i = 1, 2$) on the number of financial resources allocated to increase the resilience of the given part. This linear dependence is depicted in Figure *3*.

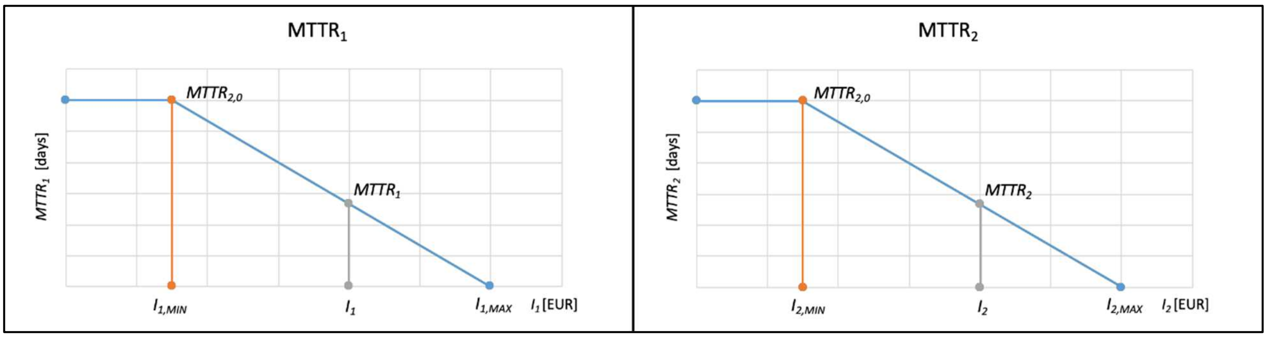

Figure 3 Linear dependency of the meantime to the recovery of two supply chain links on the number of financial resources allocated to increase their resilience

Using the general equation for a line, the $MTTR_i$ (i.e., the meantime to repair for the i-th part) when financial resources in the amount of I_i were allocated to increase the resilience of that part, can be captured by an equation (5) that uses previously defined input parameters of the model:

$$MTTR_i = \begin{cases} MTTR_{i,0} & \text{, if } I_i \in \langle 0, I_{i,\min}\rangle, \\ \dfrac{MTTR_{i,0} \cdot (I_i - I_{i,\max})}{I_{i,\min} - I_{i,\max}} & \text{, if } I_i \in (I_{i,\min}, I_{i,\max}\rangle, \\ 0 & \text{, if } I_i > I_{i,\max}, \end{cases} \tag{5}$$

Within the context of the studied problem and for the modelled supply chain, the relation defined above can only be used if the following conditions are met:

$$0 \le I_{i,\min} \le I_i < I_{i,\max},$$
$$MTTR_{i,0} > 0$$

For each part, it is now possible to determine a frequency for the repair of that part, denoted by μ_i (6) this represents the probability of transitioning from state "0" to state "1":

$$\mu_i = \frac{1}{MTTR_i} \quad (6)$$

The input parameter capturing the mean time between failures, $MTBF_i$, (7) can be used to derive the frequency of disruption for each part λ_i, which represents the probability of transitioning from state "1" to state "0":

$$\lambda_i = \frac{1}{MTBF_i} \quad (7)$$

Based on the behaviour of the modelled supply chain and the states described above, which capture the states of individual parts and hence also the supply chain as a whole, it is possible to derive a probability μ_i' (8) for each part that captures the likelihood that the i-th part will remain disrupted when transitioning from a state where that part is disrupted to the next state:

$$\mu_i' = 1 - \mu_i = 1 - \frac{1}{MTTR_i} \quad (8)$$

Similarly, for each part, it is possible to determine the probability λ_i' (9) that captures the likelihood that the i-th part will remain fully operational when transitioning from a state where that part was fully operational:

$$\lambda_i' = 1 - \lambda_i = 1 - \frac{1}{MTBF_i} \quad (9)$$

Based on findings from the theory of bulk processing and the reliability theory, a so-called system stabilization condition has been adopted, which states that $\lambda_i < \mu_i$. This condition fully complies with our understanding of disruptions within the concept of resilience applied to supply chains and their parts. In particular, disruptions are understood to refer to events that are infrequent, with an MTBF ranging in years, while their duration (MTTR) is significantly lower – days or months.

Next, the aforementioned formulas capturing the probabilities of state changes for individual parts when the Markov chain modelling supply chain undergoes a state transition are used to create formulas for calculating the transition probabilities p_{cd}, which are needed to construct the matrix containing the probabilities of transitions between individual states of the Markov chain, previously defined as $\boldsymbol{P}$. The formulas for calculating individual probabilities p_{cd} are constructed via the binary representation of the states of the supply chain as defined above. The binary number c represents the original state of the supply chain, while the binary number d (10) represents the following state of the supply chain:

$$d = \sum_{k=0}^{n-1} d_{k+1} \cdot 2^k = d_1 \cdot 2^0 + d_2 \cdot 2^1 \quad (10)$$

where:

$$d_1, \dots, d_n \in \{0,1\}.$$

The probability p_{cd} (11) for transitioning from state c to state d can then be determined as follows:

$$p_{cd} = q_1 \cdot q_2 \quad (11)$$

$$\text{where } q_k = \begin{cases} \lambda_i, \text{if } c_k = 1, d_k = 0, \\ \mu_i, \text{if } c_k = 0, d_k = 1, \\ \mu_i', \text{if } c_k = d_k = 0, \\ \lambda_i', \text{if } c_k = d_k = 1, \end{cases}$$

for $k = 1, 2$.

The matrix $\boldsymbol{P}$ (12) with the transition probabilities created from the formulas derived above then has the following form:

$$\boldsymbol{P} = \begin{pmatrix} p_{00} & \cdots & p_{03} \\ \vdots & \ddots & \vdots \\ p_{30} & \cdots & p_{33} \end{pmatrix} \quad (12)$$

In order to construct the transition probability matrix $\boldsymbol{P}$, Markov chain theory then shows that it suffices to solve the following system of equations (13), (14):

$$\boldsymbol{aP} = \boldsymbol{a} \quad (13)$$

$$\sum_{s=0}^{3} a_s = 1, \quad (14)$$

where

$\boldsymbol{P}$ is the matrix of transitions between individual states as defined based on the aforementioned relations,

$\boldsymbol{a} = (a_0, a_1, a_2, a_3); a \in \mathbb{R}^n$ is the stationary vector with the probabilities of the occurrence of individual states of the supply chain, where a_s are the stationary probabilities of individual states of the supply chain for $s = 0, \dots, 3$.

For individual states of the supply chain, it is possible to use the probabilities a_s of occurring in individual states computed in the previous calculation, along with the input parameters $V_{1,NOK}$ and $V_{2,NOK}$ specifying the relative output of individual parts when disrupted and the parameter V_{max} specifying the maximum possible output of a supply chain, to compute the outputs of the supply chain in individual states V_I^s (states of the whole chain – compared to the states of parts – where the state occurs as the upper index). This V_I^s is computed as a product of the probability a_s that the supply chain will occur in the given state, the lowest relative output of a part $V_{i,NOK}$ if at least one part is disrupted within the given state s, and the maximum output of the supply chain in the modelled period without disruptions $V_{\max}$, see Table 2.

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Table 2 Supply chain performance in individual states

Supply chain state (s)	Stationary probability of state (a_s)	Supply chain state code	Supply chain performance in individual states (V_I^s)
0	a_0	00	$V_I^0 = a_0 \cdot \min_{i=1,2} V_{i,\text{NOK}} \cdot V_{\max}$
1	a_1	01	$V_I^1 = a_1 \cdot V_{1,\text{NOK}} \cdot V_{\max}$
2	a_2	10	$V_I^2 = a_2 \cdot V_{2,\text{NOK}} \cdot V_{\max}$
3	a_3	11	$V_I^3 = a_3 \cdot V_{\max}$

For all formulas used for calculating the output of the supply chain in individual states V_I^s, it holds that the input parameter of the relative output of a part during disruption $V_{i,NOK}$ is defined as a percentage of the output that the part achieves during a disruption. This means that $V_{i,NOK}$ ranges between 0 and 1, and in other words, the calculation requires that $V_{i,NOK} \in \langle 0,1 \rangle$.

The output V_I (15) of the modelled supply chain with two parts, when financial resources in the amount of I_1 have been allocated to part SCL₁ and in the amount of I_2 have been allocated to SCL₂ with the aim of increasing resilience, can be determined as the sum of outputs of the supply chain calculated in the previous steps via the formula:

$$V_I = \sum_{s=0}^{3} V_I^s \tag{15}$$

In order to calculate the value V_0 (16) of the original output of the supply chain, i.e., when no financial resources have been allocated to increasing resilience, the same procedure as above has been used for V_I, but instead of calculating the $MTTR_i$ the calculation follows the formula:

$$V_0 = \sum_{s=0}^{3} V_0^s \tag{16}$$

where $MTTR_i = MTTR_{i,0}$. The formulas derived above can now be used to determine the value of the objective function for the allocation of financial resources to individual parts (in the amount of I_1 for part SCL₁ and I_2 for part SCL₂), as the output after increasing resilience minus the original output increased by the sum of allocated financial resources (17):

$$Z_{\max} = V_I - V_0 - (I_1 + I_2) \tag{17}$$

6.3.3 A general mathematical model for a linear supply chain

A general model for a supply chain where the parts in supply-customer relations are connected serially can be schematically depicted as in Figure 4.

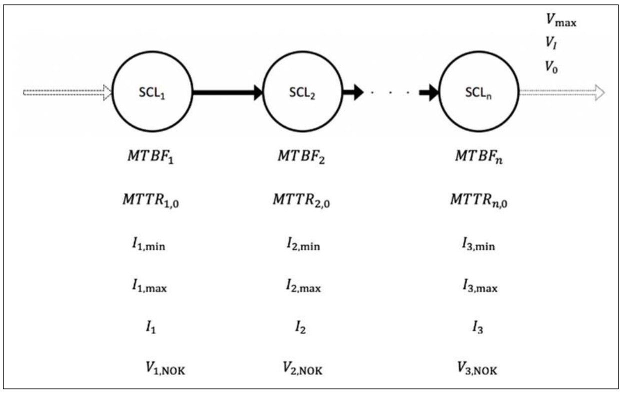

Figure 4 Scheme of a general model of linear supply chain

In order to create a general model for this setting, the core task is to construct the probability matrix that captures the probabilities of transitioning between individual states of the supply chain, i.e., the matrix denoted by $\boldsymbol{P}$. To do so, it is necessary first to define all the states in which the supply chain can lie.

The general number of elements of a set of states used to derive the general mathematical model for a linearly structured supply chain is $|\boldsymbol{S}| = 2^n$, where $n \in \mathbb{N}$ is the number of parts of the modelled supply chain and the set of all states of the supply chain is $S = \{0, 1, 2, \dots, 2^n - 1\}$. Here, the matrix with the transition probabilities is more difficult for the geometrically increasing number of states due to the accompanying geometric growth of possible transitions between these states.

In order to construct the matrix $\boldsymbol{P}$ containing the transition probabilities p_{cd} for transitioning from a state c to the following state d, we shall express the original state as c and the state after the transition as d, where these are binary numbers consisting of n (which is the number of parts of the supply chain) digits c_k based on the formulas (3) and (10) shown above. The transition probability p_{cd} (18) for moving from state c to d can then be determined as follows:

$$p_{cd} = q_n \cdot q_{n-1} \cdot \dots \cdot q_2 \cdot q_1 \tag{18}$$

where $q_k = \begin{cases} \lambda_i, \text{if } c_k = 1, d_k = 0, \\ \mu_i, \text{if } c_k = 0, d_k = 1, \\ \mu_i', \text{if } c_k = d_k = 0, \\ \lambda_i', \text{if } c_k = d_k = 1, \end{cases}$

for $k = 1, 2, \dots, n$.

The transition probability matrix ***P*** can then be calculated by the parameters derived above (formulas 6-9). Next, we can once again determine the long-term stationary probabilities for the supply chain being in individual states via formulas 13 and 14.

In general, the output V_I^s (19) of a supply chain with n parts in individual states s assuming linear connections is governed by:

$$V_I^s = a_s \cdot \min_{i=1,\dots n} V_i^s \cdot V_{\max}, \quad (19)$$

where

$$i = 1,2,\dots,n$$
$$s = 0,1,2,\dots,2^n - 1.$$

In order to compute the relative output V_i^s of individual parts of the supply chain in a specific state, i.e., to determine $\min_{i=1,\dots n} V_i^s$, it is possible to use a binary representation of the state of the parts in the state s of the whole supply chain (20):

$$s = s_n \cdot 2^{n-1} + s_{n-1} \cdot 2^{n-2} + \dots + s_1 \cdot 2^0 = \sum_{k=0}^{n-1} s_{k+1} \cdot 2^k \quad (20)$$

where

$$s_1, \dots, s_{n-1}, s_n \in \{0,1\}.$$

Then applies (21):

$$V_i^s = \begin{cases} V_{i,NOK}, \text{if } s_k = 0 \\ 1 \quad\quad , if\ s_k = 1 \end{cases} \quad (21)$$

In line with the logic underlying our calculations for two parts, the output V_I of the supply chain in the model period (after the allocation of financial resources for building up resilience) can be calculated as (22):

$$V_I = \sum_{s=0}^{2^n-1} V_I^s \quad (22)$$

The calculation of the output V_0 of the original supply chain, i.e., with no additionally allocated financial resources, is then carried out analogously as for V_I, but instead of computing $MTTR_i$, the calculation uses the formula (23):

$$V_0 = \sum_{s=0}^{2^n-1} V_0^s \quad (23)$$

Where we set $MTTR_i = MTTR_{i,0}$.

The calculation of the objective functions for increasing resilience is once again carried out using the formula (1).

6.3.4 The mathematical model calculation algorithm

Based on the presented general mathematical model, the algorithm for calculating the mathematical model is described verbally below:

1. Defining the supply chain structure (assigning supply chain links to individual layers).
2. Enter input parameters for each link in the supply chain.
3. Specifying the maximum possible performance of the supply chain and the maximum possible amount of total funds to be allocated.
4. Specifying an allocation scheme.
5. Calculation of the transition probabilities between full operation and disturbance states for supply chain links.
6. Generate all possible supply chain states.
7. Calculation of the supply chain transition probability matrix.
8. Calculation of a stationary vector of supply chain probabilities of occurrence in individual states.
9. Calculation of supply chain performance in a particular tested scheme of allocation of funds and determination of the value of the objective function.

7 Results and discussion

The aim of the presented research was to introduce a mathematical model that allows us to support our ability to determine which part of a supply chain should receive financial resources designated for increasing resilience so as to maximize the economic effect, i.e., find the most efficient way of exerting available financial resources. The introduced mathematical model allows us to carry out experiments over serial-connected supply chains and compare various scenarios for the allocation of financial resources and their impacts on the resilience of the supply chain expressed via an increase of the overall output of the supply chain in the modelled period.

Individual elements of the model do not represent separate suppliers but rather a set of suppliers who operate in a single region that may potentially be affected by the same disruptions with a certain probability. The adopted approach, however, also allows the model to treat individual companies (or individual elements of the supply chain in greater detail) as elements. Choosing one or the other approach is based on the user's needs, but the specific choice needs to be taken into account when interpreting the results of the modelling and optimization processes. In order to determine the values of the input parameters that characterize the occurrence of disruptions, historical data that could be used to statistically determine this is typically not available. In order to set these values, instead of using prediction methods based on an analysis of historical data, one can recommend the use of forward-oriented prognostic methods focusing, for example, on an analysis of the business environment, political and economic development, etc. The setup of functional dependencies for increasing resilience and the minimum as well as a maximum admissible allocation for individual parts is up to the user.

When interpreting the results of experiments carried out over the model, one needs to pay increased care since these will only be of a quality that corresponds to the quality of the input data. In order to obtain a clearer idea of the possibility for increasing the resilience of a supply chain, the scheme for allocating financial resources and the effort exerted in improving individual parts, it is recommended to perform a large number of experiments. This can be used to ascertain whether there exist multiple key parts where allocations have a similar effect, and this information could then be used in combination with other findings about the supply chain, e.g. which parts can the management improve more easily or via additional resources.

8 Conclusions

The introduced model pushes the frontiers of scientific knowledge in the area of support for decision-making when building up the resilience of supply chains. The model allows interested persons working in the area and/or from business practice to perform experiments. The fundamental contribution of the introduced model is the ability to answer the question defined in the introduction of this article, for which there was no comparable tool available prior to the one introduced in this work. One clear advantage is that the created model can be used without any changes for an arbitrary number of parts and an arbitrary layout of the supply chain. The model allows the allocation scheme for individual parts to be selected and tested. The user can use this to determine how a given allocation scheme will impact the overall output of the supply chain in the modelled period and to potentially compute the ratio of time points in which the supply chain will be located in the individual states.

The proposed model has its limitations that arise from the adopted requirements of the model. The introduced model cannot capture situations where, for example, one of the supplier parts of the chain sends part of its output also outside of the modelled system and can then redirect their production towards the customer in the chain in case of a disruption. Another limitation is the fact that it is not possible to choose different probability distributions (which could potentially be a better model for real-world supply chains) other than the exponential distribution. The possibility of sending part of the production output to a warehouse has a fundamental impact on the consequences of the disruption and the arising reduction of the output for the given part – this is especially true for shorter and less significant disruptions.

There is currently no methodology for determining the frequency of disruptions and their duration. That is why an estimate of the input parameters places significant demands on the user, especially in this area. This can be considered one of the main limitations of the introduced model; however, that being said, the same limitation also applies in general for all current models in the area of supply chain resilience, and so tackling this limitation should be a priority for future research. Even though the abstraction of resilience in the mean duration of the disruption complies with the adopted definition of resilience, this does in fact, represent a fairly prominent limitation. Accepting this prerequisite means that the model cannot faithfully model, e.g., the relationship between individual parts, flexibility, communication and other capabilities of the supply chain. A description of the dependence of improvement/increase of the resilience of individual parts via a linear equation is a significant simplification of the real world, and the same also applies to the use of the cumulative economic output as an indicator of the supply chain's output.

Based on the presented results, it is possible to provide a set of recommendations for future research in the area of building up the resilience of supply chains, supporting decision-making in this field and for the further development of the proposed model. Future research should also focus on removing the limitations of the introduced model specified in the previous subsection and arising from the prerequisites for the validity of the model. In order to increase the expressive power of the model, future extensions to the model should focus on supporting a better representation for the links between individual parts and/or on allowing for variable functional dependencies of increasing resilience on the allocation size. The model should also be expanded with the possibility of working with several types of disruptions, whereas for each disruption, it should be possible to have a separate set of input parameters. One of the aims of future research should also be to determine a good way of incorporating specific capabilities of a supply chain into the introduced model; in particular, it should be possible to set up metrics, functional dependencies for resilience improvement and a subsequent summarized expression of the chain's resilience via a unified index. Such an index would represent a managerial and user-friendly depiction of the modelling results.

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RAPID RESPONSE CENTERS FOR DISASTERS IN MEXICO: A THEORETICAL STUDY

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Abstract: After a disaster, reaction speed becomes one of the most important elements. To act in the best possible way, Disaster Operations Management must have the most accurate information on the affected area. To aid in these moments, a network of centers for Rapid Response is proposed here. Those centers would be equipped with short takeoff and landing aircraft, and would send them as soon as possible to the affected area, to gather information, and bring some type of aid. This research focuses on the theoretical foundation for such centers, including objectives, locations, missions, and equipment. This foundation is obtained through a literature review, which helps find the need for rapid response, and the main objectives and missions to be carried out. The number of centers and their locations are found by the use of a facility location model, considering the risk of each location. Finally, the number and type of aircraft needed in each center, as well as the missions for each one are found by the use of an assignment model. This research was made with the southeastern region of Mexico as its objective, but the resulting network of Rapid Response Centers could be setup in some other areas of the world.

1 Introduction

In many cases, after a disaster, logistics networks are damaged or unusable, mainly because the roads are affected. The road infrastructure can even suffer weakening after flooding. The increase in traffic before and after a disaster, sometimes caused by poorly planned evacuation procedures, and the increase in demand for supplies after a catastrophic event, adds stress to the road network, which in turn reduces, or even stops, the whole logistics network, preventing aid from arriving in the affected areas. Roads are rendered useless sometimes because of the large amount of vehicles evacuating the area, which causes strong traffic jams [1-5].

From 1900 to 2016, almost 60% of the recorded disasters in Mexico have a hydro-meteorological cause. In recent times, the southeastern region of the country has used as much as 75% of the resources for disaster recovery from the Mexican government. The region is affected by those type of events every year, causing the need for humanitarian response. Also, disasters that were accounted between 1990 and 2016 were 1.73 times more than those recorded between 1900 and 1990 [6-9].

1.1 Method

This research tries to find out if a faster humanitarian response infrastructure would be useful to reduce the adverse effects of disasters in the southeastern region of Mexico. The questions that will be tried to answer are:

1. Is there a need for a faster response after a disaster?
2. What type of objectives should such response address?
3. Are aerial operations the best solution for a faster response?

These questions are answered through a literature review in section 2. After these questions are answered, a proposal for a network of Rapid Response Centers (RRCs) to address these problems in an improved way, compared to the current situation in the country, is presented. Then the main questions of the research are answered. Such questions are the following:

4. What is the purpose and mission of the network of RRCs?
5. How many centers, and where should be set up?
6. What type of aerial equipment or vehicles should the RRCs have?

7. What type of mission should each type of vehicle perform?

These questions are addressed in sections 2 to 6, using both literature review and mathematical models. Conclusions and future work are presented in section 7, where the whole concept of the RRCs network is summarized.

2 Literature review

2.1 The need for fast response

Disaster relief can typically be divided in three phases: preparation, immediate response, and reconstruction. While addressing the three phases is needed, this research focuses mainly on the immediate response (IR) phase. When disaster has already happened, the post-disaster phase changes the dynamics of the logistics activity. The need for faster operations becomes extremely important. One of the main objectives of the humanitarian effort in that case is to reduce the average response time so that help can arrive as soon as possible [5,10-14].

During the IR phase, there are also several actions that take place, although there is no consensus among authors about the operations carried out in each phase of the disaster management cycle. Three main types of functions can be addressed in this phase: Demand management, supply management, and fulfillment management. These functions pose a challenge because of the unpredictability of the demand, as well as the many challenges arising from the disaster itself. In several research papers and literature reviews, it is noted that a lack of coordination is present in many disaster scenarios [13,15-18].

The purpose of an emergency supply network is to support the Emergency Logistics Operations, and that coordination is one of the areas where improvement can be made [19].

Question 1 is answered, because it is well established that, after a disaster, there is indeed a need for response, and as fast as possible.

2.2 The need for coordination and expedited information gathering

Many humanitarian operations have shown lack of coordination as a problem. Furthermore, when evacuation is needed, usually the demand is unknown. The importance of timely coordination after a disaster has been stated by different authors, all of them noting that it poses a challenge, and that it should be improved. One of the operations during the IR phase of DOM is the gathering of information. In many cases, maps are not the most accurate, especially in the areas where more poor people settle, and those areas usually are the most affected in a disaster. Official maps are not able to keep up with the rapid change of those settlements [1,15-17,20,21].

The characteristics of the humanitarian effort include, in many cases, the wish to bring help as soon as possible. 72 hours after the disaster could be an acceptable time frame. But to be able to bring help within that time frame, it is necessary to know what type of help is needed. This, in turn, reduces the available time to obtain information about the situation within the affected zone. It is important to reduce response time, bringing that time closer to real-time communication when dealing with DRO. Such information gathering is essential for anticipating the healthcare needs of survivors, managing critical conditions, and allocating limited resources [11,17,22-24].

The answer to question 2 is also well-established, and resides in the obtaining of information on the affected area. But some other functions can be performed, that we will address in some of the following sections.

2.3 Aerial operations

After disaster strikes, be it flooding, volcanic eruptions, earthquakes, or other types of disasters, sometimes the roads, or even the whole roadway system, are damaged, making it almost impossible to bring help to the affected areas. Sometimes it is necessary to use unconventional delivery systems to get help and supplies. Still, it is important to bring help, and as soon as possible. Speed is very important when in face of a disaster, as the arrival time of aid directly affects survival and suffering of the affected people. When the road network is damaged, or completely destroyed, communities are isolated, unless an effective way to bring supplies is established. In this cases, the best means of transport are aircraft [2,3,12,24-28].

Helicopters have long been perceived as the most practical vehicles to reach affected people when roads are damaged. In recent times, other types of aircraft have been developed, which can become alternatives for aerial operations, like unmanned aerial vehicles (UAVs), or drones [29-33].

Air transport is currently the fastest means of transport, and it is not limited by the status of the terrain. This also means that a flood, landslide, or broken road, does not prevent the operations from bringing help. Thus, the use of aerial vehicles in DRO can make sense, because help can arrive sooner to the affected area [34].

One of the areas where big advantages can be obtained from aerial operations is in the mapping of the affected zones. A high resolution map of the current situation of the area can be quickly obtained by deploying sensors and cameras aboard an aircraft, and sending such aircraft to the affected area. Unmanned aircraft, or drones, can be useful to attain such objective. Aerial survey at a close distance can also help locate victims or stranded people [29,35,36].

Mapping, victim location, information gathering for assessment of the situation, and transport of goods, are just some of the operations that can be carried out by aerial vehicles, provided that they are close enough to the affected area. If some type of aerial vehicles can be deployed quickly to perform one or more of these tasks, valuable time can be saved in the whole disaster operations management process. This, in turn answers question 3, in the sense that aerial operations are the best solution for faster response.

3 Discussion

To increase efficiency and speed in the humanitarian effort, keeping an inventory of emergency supplies close to the areas prone to suffer disasters is a commonly-used method. This method is also referred-to as *prepositioning*. Correct facility location can improve response time, by increasing the reaction speed [37-42].
Several prepositioning efforts have already been carried out, as those from Non-Government Organizations (NGOs), and others are still in planning phases, or proposals. Within the southeastern region of Mexico, a network of prepositioned inventory for disasters has also been proposed for the state of Veracruz. Most of them consider storing goods that can be sent to the affected areas in case of a disaster. Similar networks, providing services, instead of goods, have been setup using operations research methods [10,38-40,43-45]. To our knowledge, no dedicated air network of this type has been proposed to date.

The range of an aircraft, being limited, creates the need for some facilities to be located *close enough* to the possibly affected areas. If prepositioning has proved useful in the past, a *variation* of this method might make sense, by locating aircraft in facilities, so that such aircraft can arrive to the area of the disaster in as little time as possible.

4 Rapid response centers

Immediately after a disaster, response activities include, among others, search and rescue operations (S&R) and first aid medical attention. As speed is an important factor, and prepositioning is useful, it is helpful to have aerial vehicles within close distance to the affected area, ready to deploy immediately after a disaster, that can help with such operations. The main function of such vehicles would be aerial mapping, to provide useful and up-to-date information to the organizations taking part in the DOM. Additional benefits of such mapping include the location of people in need, and if possible, sending some type of help, provided that it can be packed in a compact and light manner [46].

So, as such facilities could be established, the humanitarian effort in the region could in turn be improved. The network of Rapid Response Centers has been proposed previously, including a first approach on the locations for such centers. The proposed network's goal is that no community, of the ones historically affected by disasters, is farther away than 250 km from any of the centers. This is for the affected areas to be at most one and a half hour of flight from a RRC [6,7,45].

In the following section, the location will be addressed, considering location risk factors not included in the existing solutions.

4.1 Facility location

The main objective of the RRC network is to position aircraft at the affected area as soon as possible, to start gathering information that can help improve DOM. This could mean that such centers would be located within areas that could also be affected. The correct design of a logistics network in humanitarian operations is critical. Careful planning should be done to place each of the RRCs in a safe location, while providing the best possible coverage. A similar approach has already been taken for facility location in the context of humanitarian response, within the Mexican territory, with favorable results. Although this research tries to find full coverage, instead of a maximal one [19,44,47].

4.2 Facility location considering risk factors

To consider risk within a facility location model has proven useful in research. On the other hand, to be able to arrive to the affected area as soon as possible, several facilities must be considered, so that aerial vehicles are close enough to such affected area. A facility location solution has been found previously, with a relatively simple method. A confirmation of such result, or a new one, was sought, considering risk factors. A database had already been obtained and prepared with a data mining method. A facility location model, considering locations with high risk as repellants, and locations with existing shelters as attractors, was solved. The model also included a maximum distance from every location to the closest center [6,7,43,47].

This model resembles the constrained Weber problem with attraction and repulsion. In that model, a single source is sought, and sinks may attract or repel the source. This model uses the multi-source approach, that has already been studied extensively in the past. The model tries to minimize the Euclidean distance, but the cost of travelling such distance is modified by the attractors and repellants calculated from the risk factors, and the cost of setting up each service center is also considered. A maximum distance is also set up as a restriction [48,49].

The mathematical formulation of the model is the following (1)-(6):

$$minimize \sum_{i=1}^{n}\sum_{j=1}^{m} u_{ij} w_{ij} \left(\sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}\right) + c_i s_i$$

s.t.

$$\forall j \le m: \sum_{i=1}^{n} u_{ij} = 1 \quad (1)$$

$$\forall i \le n: c_i s_i > \sum_{j=1}^{m} u_{ij} \quad (2)$$

$$\forall i \le n, \forall j \le m: u_{ij}\sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \le d_{max} \quad (3)$$

$$\forall i \le n, \forall j \le m, \forall k \le o | R_{kj} \ne 0 \; \& \; \sqrt{\left(x_i - x_j\right)^2 + \left(y_i - y_j\right)^2} \le r_j : w_{ij} =$$

$$\prod_{k=1}^{o}\left(1+R_{jk}\left(1-\frac{\sqrt{(x_i-x_j)^2+(y_i-y_j)^2}}{r_j}\right)\right) \quad (4)$$

$$\forall j \leq m, \forall i \leq n : u_{ij} \in \{0,1\} \quad (5)$$

$$\forall i \leq n : s_i \in \{0,1\} \quad (6)$$

Where the decision variables are:

x_i, y_i are the *x* and *y* coordinates of the service center *i*, greater than zero.

s_i is a binary indicator, 1 if service center *i* will be set up.

u_{ij} is a binary indicator, 1 if service center *i* will serve the location *j*.

And the model parameters are:

n is the number of service centers, m is the number of locations to serve.

w_{ij} is the weight factor, adjusted by attractors and repellants, of travelling from *i* to *j*.

x_j, y_j are the *x* and *y* coordinates of location *j*, greater than zero.

c_i is the cost of setting up service center *i*.

d_{max} is the maximum allowed distance from the service center to each location.

o is the number of risk factors to be considered.

r_j is the risk radius of location *j*.

R_{jk} is the risk factor *k* of location *j*.

The restrictions, explained, are:

1. The sum of *used* for each location must be 1, every location must receive service from one service center.
2. The cost of setting up each service center must be accounted for.
3. The distance from each location to its used service center must not exceed the maximum distance.
4. The *weight* of travelling from a location to its assigned service center gets altered by the risk factor. It is multiplied by 1+the risk factor, thus attracting or repelling the service center.

4.3 *Solving method for locations*

For the multi-facility weber problem, the Simulated Annealing algorithm is one of the most effective options. This algorithm requires the presence of an initial solution. A previous research considering rapid response centers, but not considering risk factors, was used as the initial solution for the current model [7,50-52].

4.4 *Facility location results*

Instances considering five to seven centers were solved, obtaining the best results with six centers, considering risk factors. The nature of the RRCs prevents them from being setup anywhere, mainly because they need to be resupplied. Should a disruption on the supply chain of the center be present, the goal of said center would not be achieved. As such, there is the need to care for the center itself. The center must then be placed within close distance of existing supply chains. The proposed locations for each center are the closest town or city to the raw result of the model. These locations are presented in Table 1. This, in turn, answers question 5, showing that 6 centers should be placed in the mentioned locations [53].

Table 1 Facility location model results

Center	Latitude	Longitude	Closest Town/City
1	16° 34' 52.32"	-96° 18' 49.68"	Santa María Zoquitlán, Oax
2	20° 34' 23.88"	-89° 0' 17.28"	Sotuta, Yuc
3	17° 14' 56.04"	-97° 24' 1.08"	San Juan Diuxi, Oax
4	16° 46' 55.56"	-92° 15' 19.8"	Abasolo, Chis
5	20° 2' 40.2"	-97° 57' 51.48"	Tepetla, Pue
6	18° 0' 5.76"	-99° 16' 31.44"	Tulimán, Gro

5 RRCs Mission

To improve the effectiveness, and reduce the response time of all the actors in the humanitarian effort after a disaster, the best possible and up-to-date information should be obtained. Operators of the vehicles pre-positioned at each Rapid Response Center could perform the task of Aerial Surveillance, as soon as possible after disaster has occurred. Aerial photo or video of the area, with enough resolution for decision makers within the DRO management to evaluate the situation, is the expected main result of such flights [29,36].

If the vehicles are not large, their operational cost should also be small, although that also comes with a limitation on the side objectives such vehicles can attain. Still, they can be helpful when combined with other types of vehicles. Small vehicles that are not capable of evacuating a person, or a family, can still be equipped to mark the place where those people can be found, and then a larger vehicle can be sent specifically for that task. Smaller unmanned vehicles can access places that manned aircraft can't reach. Smaller vehicles can be used for last-mile delivery of goods in disaster scenarios. A vehicle too small for evacuating procedures could still be large enough to carry small and light survival or first-aid emergency kits, that could be air-dropped very close to people that need them. These two secondary objectives can help reduce the overall cost of the DRO, and improve the effectiveness of the humanitarian effort [32,54,55].

The answer to question 4, the mission of the RRCs, is then:

1. Aerial Surveillance As Soon as Possible After Disaster (Information Gathering),

2. Emergency Evacuation Marking,
3. Air-Drop of Basic First-Aid / Survival kits.

6 Mission assignment

6.1 Types of aerial vehicles

Different types of vehicles can perform different tasks. From a distance point of view, fixed wing and large aircraft can be helpful outside of the affected area, and helicopters or smaller aircraft can be useful within the affected area. When disaster operations are still on its planning stage, having as much information as possible on the disaster effects is paramount, but DRO do not have infinite resources, so larger aircraft with higher operational cost should be used carefully. On the other side, the size of technological devices has been decreasing steadily, and is currently small enough for cameras and sensors to be fit on smartphones or wearable devices. Such sensors could be mounted on almost any aircraft, but to carry some type of cargo, there are size limitations [23,25,56-58].

To classify the different types of aircraft that could be used for the RRCs, three main categories could be considered. First, the size of an aircraft, which directly affects its ability to maneuver through the affected zone, while also determines how much the ship would be affected by wind and weather. Second, the type of lift or propulsion, which affects its maneuverability, speed, and range. Third, cabin type, because aircraft design follows very strict rules, and usually makers design the aircraft specifically for passengers, or cargo, although some cross applications can be found. Still, the cabin type can be used or adapted for different applications, so the types of aircraft will only be classified by size, and lift technology [59-64].

The types of vehicles, divided by lift type, that can be considered, are:

1. Fixed hard wing. Where lift is provided by one or more wings, which remain fixed in place, although some parts of them might still be moving [65].
2. Flexible wing. Where the lift is provided by a large surface of flexible material, like fabric. Can have a hard frame or only the flexible parts [61].
3. Powered rotary wing. Lift is provided by a series of wing-shaped blades or rotors connected to an engine, where the rotation of such wings provide lift. One or two sets of such wings shall be considered in this category [66].
4. Powered multiple rotary wings. Like the previous category but using three or more rotors. Samples between 3 and 8 rotors are currently available in the market, and are increasing in popularity [67].
5. Unpowered rotary wing. Where lift is provided by a rotor, but it spins freely, without power from an engine. The vehicle uses a powered propulsion method, and the rotor spins because of the air flow through it, producing lift [68].
6. Tilting powered rotary wing. A combination of a fixed wing for large distances and higher speeds, but with large propellers or rotors that provide lift at takeoff and landing stages [69].
7. Lighter than air. Vehicles that do not use a wing, but a large container of a fluid with a lesser weight than that of air [70].

The *size* category can vary greatly, depending on the type of scale that would be used. A simple scale can be created for this, depending on how many passengers or weight such aircraft could carry. Unmanned aircraft, not big enough to carry 20 kilograms will be considered very small. Aircraft capable of carrying more than 20 kg, or from 1 to 4 people will be considered small, 5 to 20 people will be considered medium, 21 to 60 will be considered large, and anything larger than that will be considered very large.

Very large aircraft pose too many challenges for the type of operations proposed in this study, they require large landing strips, and their operational cost is too big. Those will be discarded. Very small aircraft with multiple powered rotary wings are currently found in many places around the world. These aircraft could also perform the search function, but the current state of such technology has a strong range limitation, averaging only 7 kilometers. This average range limitation could also be considered for other types of lift technology, but with the same size. Also, weather affects smaller aircraft more than larger ones, and some disaster types cause bad weather that could prevent very small aircraft from flying, and performance is currently not enough for them to be practical for the RRCs needs. Very small aircraft, of any lift type, will be discarded [67,71,72].

The type of lift of an aircraft also affects its ability and range. Lighter than air vehicles, like hot air balloons, or zeppelins, tend to have a very low speed. As speed is an integral part of the RRC network objective, lighter than air ships will be discarded. Additionally, some combinations currently do not exist. Flexible wings can only be found in small aircraft, multiple (More than two) powered rotary wings can not be currently found in medium or large vehicles, and finally, although there was a medium sized prototype of an unpowered rotary wing vehicle long time ago, those can only be found in small size in present times. Currently only one tilting rotor aircraft is available, and it is a medium aircraft, although some other vehicles of the same type are currently under development [70,73-75].

The size and type of lift, average speed of each type of aircraft, average landing/takeoff distance, and average carrying capacity (passengers or cargo) was compiled in Table 2, using publicly available information. As bad weather can affect the flight characteristics of each type of aircraft, usually less as size increases, a *Weather Sensitiveness* factor was included. This factor is 0 if the aircraft can fly in severe weather conditions, and 3 if it can not. If the aircraft can land in small spaces, and carry victims, the *Rescue* value is 1. The passenger capacity was considered as the average capacity of the size category [76-79].

Table 2 Aircraft types and characteristics

Aircraft Wing Type	Purchase cost (USD)	Cost / Hour (USD)	Speed (Km/h)	Rescue	Weather Sensitiveness	Cargo
Large fixed	50000000	1500	600	0	0	3
Medium fixed	3000000	500	300	0	1	3
Small fixed	500000	130	200	1	3	2
Small flexible	15000	45	70	1	3	0
Large powered rotating	12000000	400	300	1	1	3
Medium powered rotating	2000000	200	250	1	2	3
Small powered rotating	1000000	145	170	1	3	2
Medium multiple powered rotating	1000000	60	110	1	2	1
Small multiple powered rotating	500000	30	90	1	3	0
Small unpowered rotating	150000	50	160	1	2	1
Medium tilting	73000000	9000	450	1	1	3
Small tilting	20000000	4500	300	1	3	3

6.2 Disaster types

The type of disaster has a large influence on the type of vehicles and operations that could be performed by the vehicles of the RRCs. An earthquake's maximum duration is under 2 minutes, which does not prevent aerial vehicles from staying airborne, but volcanic eruptions do. Heavy rain and winds can be dangerous for smaller aircraft, but larger ones could resist the weather. On the other side, the cost of flying larger aircraft can be so high that some missions, like search and surveillance, consume too much resources, while smaller aerial vehicles can perform such missions at a much lower operational cost [80,81].

Table 3 Disaster types to be considered

Disaster Type	Weather Disruption Level	Aerial Evacuation	Survival Kits
Rain	2	1	1
Hurricane	3	1	2
Flooding	1	1	3
Volcanic Eruption	3	0	1
Slide	1	1	1
Earthquake	0	0	0

The types of disasters that will be considered, as shown in Table 3, are those found in previous research [47]: Rain / Hurricanes, Flooding, Volcanic Eruptions, Slides, and Earthquakes. Of those types, volcanic eruptions and hurricanes prevent all or some types of vehicles from flying, while the other types allow the operations of aircraft. Slides, flooding, and earthquakes can cause damage to a landing strip or facility within the affected area. Flooding or hurricanes can call for immediate evacuation of people trapped atop of buildings, that cannot be done by land, while after earthquakes usually evacuation can be done by land [80,82,83].

6.3 Assignment model

To reduce as much as possible the cost associated with the aerial operations on a disaster scenario, a mathematical model was used. On one side, the types of disasters that have already happened in the region, with the limitations they impose on flight operations, reconnaissance missions, or rescue operations. On the other side, the types of aircraft suitable for the RRC missions, with their limitations, and their average operating costs will also be considered. The model seeks the minimal cost associated with the missions performed in a disaster scenario.

The reconnaissance mission can be performed by any type of aircraft, and it can be performed at the same time as the air drop and rescue missions, so it is not considered for the model. The ability to perform the rescue and air drop missions depend heavily on the type of aircraft, and will be considered in the model. If the weather sensitivity of the aircraft is smaller than the weather disruption level of the type of disaster, such aircraft is not suitable to perform that mission in that disaster scenario. The same treatment is done to the need/ability to rescue victims. Aerial evacuation requires the ability to land in an unprepared space, or to hover above the victims while the procedures are carried on. For that purpose, some VTOL capacity would be required to cover the Aerial Evacuation need. The Survival Kits column considers the possibility to air-drop said kits from a close distance to the victims. More cargo carrying capacity means more kits and bring such help to more people, but at the same time, larger vehicles must have larger space to maneuver, and smaller vehicles can come closer to the affected people.

Current UAVs have strong range and endurance limitations, but those were omitted in the model, to give room for improvement of such technology. Some other considerations were made to ease the model solving. The time to rescue one victim was standardized to 30 minutes, and the maximum duration of a mission was set to 8 hours. Missions were required to be completed within a 48 hour time frame.

Several runs of the model were desired, one for each disaster type. The distance from the RRC to the affected area was tested using values of 25km, 125 km, and 250km. The number of victims in need for evacuation or air drop of kits was also changed, using 10, 50 and 100 victims. For each type of disaster, a combination of each case of distance and victim combination was set up as a scenario. The resulting list contains 9 scenarios for each disaster type. The model was prepared to find, for each disaster type, the combination of vehicles that would represent the lowest acquisition and operating cost to cover the needed operations in all scenarios, considering the abilities of each type of aircraft.

The mathematical formulation of the model is the following (7)-(15):

$$minimize \sum_{i=1}^{n} v_i a_i + \sum_{j=1}^{m} h_i mt_{ij}$$

s.t.

$$\forall_{i\le n}: v_i \in \mathbb{N} \quad (7)$$

$$\forall_{j\le m}: \sum_{i=1}^{n} \frac{r_{ij} v_i p_i}{rph} \ge vn_j \quad (8)$$

$$\forall_{j\le m}: \sum_{i=1}^{n} s_{ij} v_i \ge \sum_{i=1}^{n} r_{ij} v_i \, spv \quad (9)$$

$$\forall_{j\le m, i\le n}: mt_{ij} = t_{ij} + s_{ij} + r_{ij} \quad (10)$$

$$\forall_{j\le m, i\le n}: t_{ij} \ge 2\frac{d_j}{sp_i}\left(\frac{s_{ij}+r_{ij}}{s_{ij}+r_{ij}+0.001}\right) \quad (11)$$

$$\forall_{j\le m, i\le n}: mt_{ij} \le md \quad (12)$$

$$\forall_{j\le m, i\le n}: mt_{ij}(wd - ws_i) \ge 0 \quad (13)$$

$$\forall_{j\le m, i\le n}: rn_j r_{ij} \le ra_i r_{ij} \quad (14)$$

$$\forall_{j\le m, i\le n}: kn_j mt_{ij} \le ca_i mt_{ij} \quad (15)$$

Where the decision variable v_i is the number of vehicles of type i to be used.

And the parameters are:

n is the number of different types of aircraft
m is the number of different disaster types
a_i is the acquisition cost of type i vehicles
h_i is the cost per hour of type i vehicles
mt_{ij} is the total mission time of type i vehicles for scenario j
r_{ij} is the rescue time of type i vehicles for scenario j
p_i is the passenger capacity of type i vehicles
rph is the standardized number of victims per hour that can be rescued
vn_j is the number of victims in scenario j
s_{ij} is the search time of type i vehicles for scenario j
spv is the standardized search time per victim
t_{ij} is the travel time of type i vehicles for scenario j
d_j is the distance to the affected area in scenario j
sp_i is the average speed of type i vehicles
md is the standardized maximum mission duration
wd_j is the weather disruption in scenario j
ws_i is the weather sensitivity of type i vehicles
rn_j is the need for rescue in scenario j
ra_i is the rescue ability of type i vehicles
kn_j is the need for survival/first aid kits in scenario j
ca_i is the cargo ability of type i vehicles.

The restrictions, explained, are:

1. The number of vehicles must be an integer greater than 0.
2. The number of rescue hours must be enough to rescue all victims for each scenario.
3. The number of search hours must be that of the rescue hours multiplied by the search time per victim.
4. Mission time equals travel, search, and rescue times for each scenario.
5. Travel time is considered only if the vehicle performs search or rescue time.
6. Mission time must not exceed the maximum mission duration.
7. The vehicle type's weather endurance must be larger than the scenario's weather disruption.
8. The vehicle type's rescue ability must be larger than the scenario's rescue need.

The vehicle type's cargo ability must be larger than the scenario's kit need.

6.4 *Assignment model results*

The model was solved assuming that all types of vehicles have unlimited range. This was done to provide room for future growth in technology, mostly in UAV range and speed, but not limited to those types of aircraft. Results included the search, rescue, and travel time for each scenario and type of vehicle, and it was observed that the optimal vehicle combination for each one included a predominant mission for each type of aircraft, where some aircraft were preferred for search operations, and some for rescue operations. A table with those results was compiled and is presented in a simplified way. Table 4 shows the summarized results for each scenario, where the number of missions required to rescue all the victims is shown. The letters next to the number of missions show if the predominant mission is search (S), rescue (R), or both (S&R).

It is worth noting that the model shows large fixed wing aircraft as the ones preferred for earthquake scenarios, which were not marked as having STOL requirements, the explanation for this result lies in the assumption that airports might still be operational in such disaster scenario, and the possibility to evacuate people by land in such disaster type. It is noteworthy that, with the exception of earthquakes, all the other disaster types required a combination of vehicle types. Small vehicles with low operating costs are preferred for search operations in all scenarios, and powered rotating wing aircraft, or *helicopters*, are preferred for rescue operations.

Each mission can last up to 8 hours, and the effectiveness of the RRCs is larger between 0 and 48 hours after the disaster, so each aircraft could perform up to 6 missions in that time frame. The results of the model should then be divided by 6, to obtain the recommended quantity of aircraft for each scenario. This answers questions 6 and 7, the type of aerial vehicles that RRCs should have, and the type of mission each type of vehicle should perform.

Table 4 Number of vehicles resulting from the assignment model (Empty categories deleted)

	Number of missions					
Vehicle type	**Rain**	**Hurricane**	**Flood**	**Volcanic Eruption**	**Slide**	**Earthquake**
Large fixed wing						4 S&R
Medium fixed wing			2 S		2 S	
Small fixed wing		4 S				
Large powered rotating wing		1 R	2 S&R		2 S&R	
Medium powered rotating wing		1 R				
Medium multiple powered rotating wing	7 R			7 R		
Small unpowered rotating wing	12 S			12 S		

7 Conclusions

The main conclusion of the current theoretical study is the overall definition of the Rapid Response Centers, considering the locations obtained by solving the facility location model, and the suggested mission alignment, with the combination of vehicles obtained with the assignment model. They are the following:

Rapid Response Center for Disasters.

A network of facilities is proposed, with aerial vehicles ready to launch, that would perform the tasks of **information gathering, search for victims, and air-drop of small first-aid or survival kits**. The facilities would contain the adequate spaces to store, maintain (lightly) and launch or receive the aircraft. Landing spaces for Short/Vertical takeoff and Landing vehicles, fueling and control facilities should exist within the facilities. The centers also would need storing facilities for the small first aid or survival kits, and an adequate stock of such kits. Finally, the centers should have adequate data links to send the gathered information to the DRO management.

The suggested locations for the centers consider a maximum distance of 250 kilometers from every historically affected location to its closest center. The locations considered are: Santa María Zoquitlán, Oax; Sotuta, Yuc; San Juan Diuxi, Oax; Abasolo, Chis; Tepetla, Pue; and Tulimán, Gro.

The missions carried out by the aircraft in the RRCs are:

Information Gathering. Aircraft would be launched as soon as possible after disaster, to fly-over the affected area, obtaining video and photos of the zone. This information would be relayed to the DRO management, to provide a better knowledge of the state of the disaster zone.

Search and Rescue. While gathering photo and video, aerial operators can spot victims requiring evacuation or help. Depending on the capacity of each aircraft, either the evacuation procedure is carried on, or the place where there is the need for rescue is marked. If the aircraft is not big enough to perform the evacuation, it would mark the place and need for evacuation, and DRO would then send an adequate aircraft for the task.

Emergency kit Air-Drop. When victims are found that need help, but not immediate evacuation, a small emergency kit could be dropped close to them. The kit could be the one proposed in previous research: An emergency food bar, water filter/water purifying tablets, first aid kit (adhesive bandages, antiseptic towelettes, sterile gauze), and an emergency thermal blanket [45].

The required vehicles are:

It is suggested that each RRC contains 2 small unpowered rotating wing vehicles, or 2 medium fixed wing vehicles with STOL capabilities, for search operations, and one large powered rotating wing vehicle, or helicopter, for rescue operations. The search vehicles would be launched as soon as possible after a disaster has struck the coverage area of the RRC, to perform the search and information gathering missions. The same aircraft would mark the places where victims are located, so that the rescue vehicle can perform such task without time loss.

7.1 Future work

Very small aircraft can reach places where aircraft of other sizes can not, but their main limitation for this purpose is their range and low stability, which in case of heavy winds or rain could prevent them from flying. Still, a different approach on the RRCs, with mobile carriers, that could get close to the affected area by land, and then deploy the aircraft as a swarm, could mean that the main mission of the RRCs is possible with a different approach. Such approach could be evaluated in future work. On another side, a more comprehensive data collection on aircraft types and abilities, as well as for disaster scenarios, could represent a more accurate result on the assignment model.

Many areas of the RRC network are still not covered, like the physical design of the centers, as well as a detailed function and procedures description for each working place. Such research could result in a valuable source of information, should the actual network of RRCs be setup.

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RAIL DELIVERIES OF BULK OIL CARGOES FROM THE CASPIAN REGION TO EUROPE

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Abstract: This article is a study of the current situation with rail deliveries of bulk oil cargoes from the Caspian region to Europe. It addresses the importance of these deliveries for the European energy security, the salient features of rail transportation of crude oil and refined products in this direction, the main transportation routes, and, finally, describes existing and potential problems with rail deliveries of bulk oil cargoes from the Caspian region to Europe and suggests potential resolutions for these problems. In spite of the serious importance of the topic, the overall number of scientific publications related to it is limited. Another problem is that existing scientific literature sources tend to cover general transportation or geopolitical aspects without paying due attention to the rail transportation, logistical problems, related to the current topic, and how to resolve them. The author attempts to fill these knowledge gaps by collecting, processing, and analysing first-hand information from the main market players. The author concludes the article emphasising the importance of the railway transport for deliveries of bulk oil cargoes and pointing out that several important actions are required, namely the actual introduction of a competitive freight market and transition from transport to logistics corridors, support from governments and railway administrations and proactive position of shippers.

1 Introduction

The countries bordering the Caspian Sea include Azerbaijan, Iran, Kazakhstan, Russia and Turkmenistan. The map of the region is given in Figure 1 below.

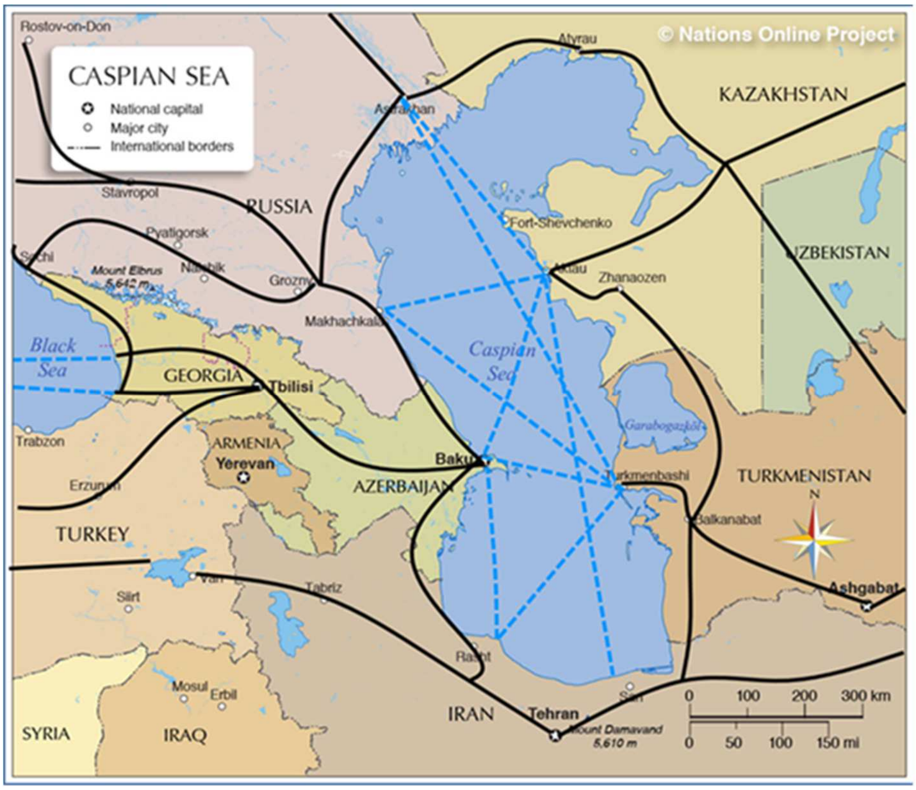

Figure 1: Caspian Sea region. Major railways and seaways
Source: [1] and own drawing

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One can ask if bulk oil supplies represented by crude oil and refined products from this region are important for Europe. Figure 2 and Figure 3 below give answers to this question, demonstrating that three out of five Caspian countries, namely Azerbaijan, Kazakhstan, and Russia, are among the largest crude oil and petroleum oils suppliers to the European Union (EU). Terms "refined product", "oil product" and "petroleum oil" are used interchangeably throughout this document. These facts clearly define the role of the region for European energy security. Iran is excluded from consideration because of the Western sanctions, which were tightened in 2019 [2]. This resulted in the discontinuation of Iranian crude supplies to the EU.

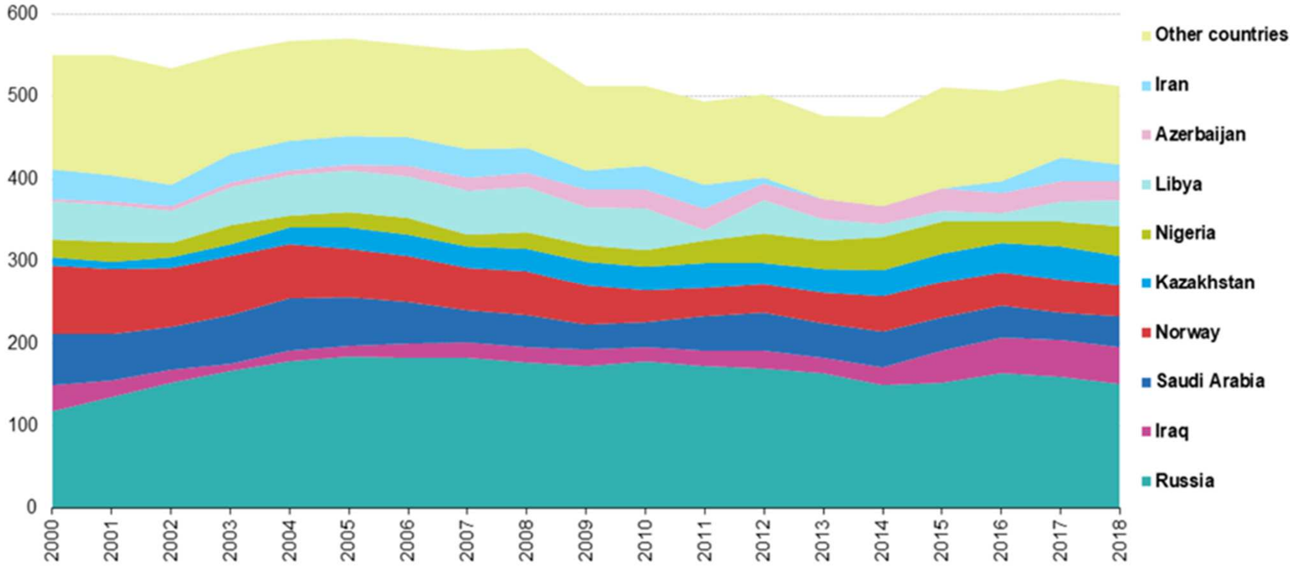

Figure 2. Crude oil imports by country of origin, EU-28, 2000-2018 (million tonnes)
Source: [3]

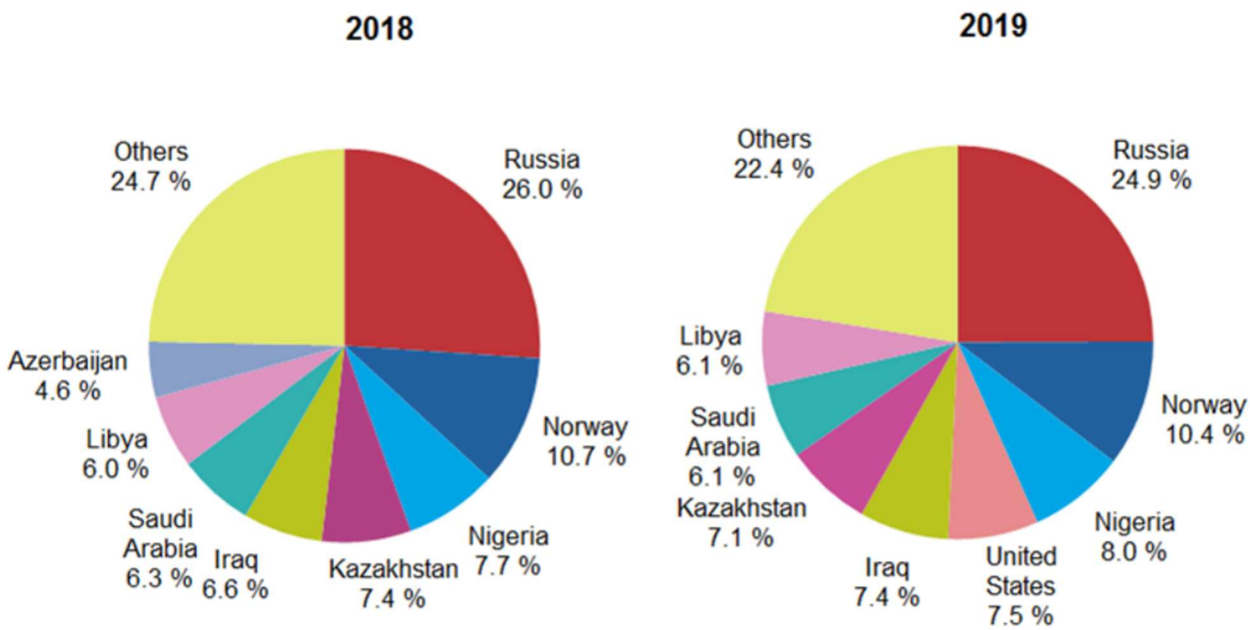

Figure 3. Extra-EU imports of petroleum oils from main trading partners, 2018 and 2019 (share (%) of trade in value).
Source: [4]

This dependence is mutual. [5] pointed out that "The economy of Europe depends on energy imports, while the economy of the Caspian region depends on energy exports."

Even though this region is one of the closest to Europe geographically, the distance between them is huge and measured in thousands of kilometres. This defines the significance of transportation in general and of railways in particular. It is also important to note that „An important aspect of the European policy is to enhance the role of railway transport" [6].

The following knowledge gaps exist at the moment, and this is shown in the Literature Review section below:

1. In spite of serious importance of the topic, the overall number of scientific publications, especially in English, related to the rail deliveries of bulk oil cargoes from the Caspian region to Europe is limited;
2. Existing scientific literature sources tend to cover general transportation or geopolitical aspects without paying due attention to the rail transportation, logistical problems, related to the current topic, and how to resolve them.

This article attempts to close these gaps.

The research questions follow from these knowledge gaps and may be summarised as follows:

1. What are existing and potential problems related to rail deliveries of bulk oil cargoes from the Caspian region to Europe?
2. What are the ways to resolve these problems?

2 Literature review

Rail deliveries of bulk oil cargoes from the Caspian region to Europe are not in the limelight of researchers. However, the author has collected and reviewed as many sources as possible. He also widely used information gathered at oil and transportation conferences and other professional events he attended over the past few years.

As already mentioned above, the number of scientific publications addressing the topic is small. They, however, exist and are listed here. It is interesting to note that back in the 90s [7] complained that "too much oil to ship by rail or barge; pipelines are more efficient and less expensive options for carrying cargo across great distances". The situation now is completely different and will be described further below.

A substantial part of scientific publications related to the topic of this article are in Russian. They include the works of [8-16] and of many others. We should note the work of [17] about export deliveries of oil and petroleum oils separately. He considered flows, routes and transport mode's competition. This work forecasted the decrease in rail deliveries by 2020, and this forecast materialised. [18] provided a comprehensive analysis of oil and oil products flows via Russian maritime ports.

Also, the author managed to find many interesting scientific publications on the topic written in English as well. Among deserving due attention are the publications by [19] who examined "the ways in which CIS oil industries have been organised and governed since 1991, as well as questions of transport infrastructure and export routes, which are especially critical for Central Asia's landlocked producers." In their another publication [20] concluded that "policy-makers can do much to raise or lower the long-term elasticity of CIS supply. Unfortunately, policy in the region seems, on present trends, likely to lower it." This point is still valid after more than ten years. [21] addressed a whole range of issues related to the Trans-Caspian energy route, including "the implications of the August 2008 crisis in Georgia for the prospects of the expansion of the westbound route and for the future of Caspian energy export routes in general", „the complex relationship between Azerbaijan and Kazakhstan and their companies involving rivalry, competition and cooperation in the westward oil export", etc. [22] reiterated that "European markets represent the most profitable option for the export of Azerbaijani oil and gas". [23] mentioned that "the EU and Kazakhstan agreed in January 2015 to initiate a new "Enhanced Partnership and Cooperation Agreement". But the energy field has not explicitly been defined as one of the "main areas of cooperation' despite Kazakhstan being the third-largest non-OPEC supplier to the EU." [24] examined "alternative transportation lines in the (Caspian) region, reveal the current problems, and propose solutions within the context of infrastructure or transport policies."

It is necessary to mention that a substantial portion of scientific publications is devoted to the geopolitical aspects of crude and oil products supplies from the Caspian region to Europe. Such works include [25-29] and many other. We should also mention [30] who analysed "how the security of oil supply to the European Union member states could be enhanced in case of a lasting supply disruption…" and found that "Ultimately, this depends on the ability to feed a sufficient amount of refining capacity, which would in turn supply refined products to the market." [5] examined „the security of demand for the oil and gas of three countries in the Caspian region".

Some scientists investigated the significance of Caspian hydrocarbon supplies for the EU. [31] wrote that „West European countries perceive increasing their supplies from the Caspian region as a way to lessen their dependence on oil coming from OPEC-associated countries, especially the Persian Gulf." [32] advised that „Caspian energy resources have the potential to substantially diversify Europe's energy supplies away from a current over-dependence on Russia. If supported by the appropriate policies, Europe has the potential to, in several years, emerge as better-situated and stronger vis-à-vis Russian energy dominance."

Researchers addressed the issue of improper development of transport and logistics services in the region. For example, [33] examined "Russia's entire oil and gas export network and reveals that there is a considerable surplus pipeline capacity, which is likely to endure in the future. It brings to attention surplus capacity as a concept..." It is obvious that the excess pipeline throughput capacity has negatively affected the volumes transported by rail.

Though very limited in number, some publications still describe and analyse the rail transportation of oil and oil products. They include the already mentioned excellent report on the Caucasus Transport Corridor prepared by the World Bank: "This study evaluates the potential demand for oil and oil products transport via the existing rail corridor in the Caucasus, considering the competition from alternative routes" [34]. [35] who points out that „From the point of view of the operation of railway transport, oil and oil products occupy a large share in cargo operations, but an even larger share in Russian Railways' income". This point is echoed by [36,37], who wrote that „One of the most important segments of the transport market of the Republic of Kazakhstan is the transportation of oil cargo".

As mentioned earlier, transportation of crude and petroleum oils from the Caspian region to Europe has received limited attention from researchers. This is why the author used other sources of information. The most interesting and reliable sources include publications of Eurostat, international organisations and financial institutions, oil companies and specialist journals.

3 Methodology

The descriptive part of the article (Current situation) is based on the review of different literature sources as well as on the information gathered at oil and gas conferences and other professional events. In 2019 and 2020, the author attended and spoke at various professional events in Azerbaijan, Hungary, Kazakhstan, the Netherlands and Russia.

The part devoted to existing and potential problems related to the topic is mainly based on in-depth semi-structured one-to-one interviews through literature sources were also used. In 2019 and 2020, the author interviewed 20 individuals working for oil and transportation companies and traders, i.e., those involved in the transportation of oil bulk cargos from the Caspian region to Europe. 14 out of 20 interviews were face to face. The rest took place via VoIP applications (WhatsApp and Skype).

The list of interviewees is given in Appendix A below. The sample is representative because the author approached most of the main market players. Please note that this is qualitative research, so the data obtained are non-numerical. This research had the following main steps:

- Collecting information through the relevant literature review;
- Collecting information through interviews;
- Transcribing and cross-checking the answers;
- Analysing the answers and the information collected through the relevant literature review;
- Summarising the collected information.

The respondents (terms "interviewee" and "respondent" are used interchangeably throughout this document) were requested to (i) list and describe the main problems shippers face in the process of rail transportation of crude and oil products to Europe and (ii) suggest ways to resolve them.

The answers on the first question were cross-checked to ensure their trustworthiness. The answers to the second question were not cross-checked as they represent not the real situation but rather the ways to change it. However, the interviewees were asked to give their opinion on potential solutions proposed by others. Several follow-up calls were made in order to clarify and ascertain the information.

Limitations of this research are described in Conclusions.

In 2019 and 2020, the findings described in this article were reported at the professional oil events in the countries mentioned above and were positively accepted.

4 Current situation

4.1 Rail transportation of oil cargoes

The points below are important for understanding the transportation of crude oil and petroleum oils from this region to Europe by rail:

- Railways are used for transportation of a major part of refined products and of a smaller part of crude oil transportation. This is also the only mode used for transporting sulphur, which is a by-product from sour crude oil and gas processing. In case of crude transportation, rail is used in the absence of direct access to pipelines or tankers and in the situations when a producer wishes to retain quality and consequently the value of its crude since there is no quality bank in the Russian crude oil pipeline network;
- Rail volumes of bulk oil cargoes have been decreasing over the last years. Mainly because of large-scale construction of new oil product pipelines in Russia and obscure rail rate policy "The share of oil and refined products (in the total shipments of Russian railways) continues to decline: in 2016 it was 19.3%, in 2017 - 18.7%, and at the end of 2018 it reached 18.3%" though they remain "…the second largest cargo for Russian Railways" [35];
- Railways not only compete but also serve as a backup option in case of problems with pipelines. The last case was in April-June 2019 when organic chlorides contaminated parts of the Russian crude oil pipeline network;
- There is the strongest influence of political situation on transportation routes;
- The attention of governments and railway administrations of the region is focused on attracting transit traffic;
- The regional railway and trans-shipment infrastructures are undergoing continuous improvement. Large infrastructure investments have been made since the dissolution of the former Soviet

Union. However. there are significant imbalances as the current usage of the regional railway, and oil trans-shipment infrastructure is far from optimal;

- Multimodal (pipeline or rail and then marine) is the main mode of crude oil and oil products transportation from this region to Europe;
- Rail deliveries are certainly more expensive than marine or pipeline transport, but their importance remains significant, which will be described further below.

4.2 Main routes

This section describes the crude oil and refined products rail deliveries through the example of each country.

Azerbaijan: Crude oil is transported by rail to the Georgian Black Sea ports in relatively small volumes as the main crude oil goes via pipelines. Azeri and much smaller volumes of Kazakh and Turkmen products are railed to Georgia's Black seaports. After reaching seaports, crude and refined products are transshipped onto tankers and then delivered to European ports.

Iran: As mentioned above, this country is excluded from consideration because of the Western sanctions.

Kazakhstan: Since the collapse of the former USSR, the country has built more railways than any other post-Soviet country. Kazakhstan, the main crude oil producer in the Caspian region, exports most of its crude oil to the European markets. In the case of rail deliveries, Kazakh crude and products mostly go to Russia's Black Sea ports. Smaller amounts are delivered to Russia's Baltic Sea ports. The ports of such countries as Estonia, Latvia and Lithuania are also used, but this traffic is decreasing. Georgia's Black Sea ports are used as well, especially in winter periods, though the logistics of this route is cumbersome.

Russia: The country is the main producer of products in the Caspian region, though, as mentioned above, its crude production in the Caspian region is relatively small. Russia is also the biggest transiter in the region thanks to its geography, and it exercises this advantage to the full extent. It also has a well-developed and comprehensive transport infrastructure. In addition to its geographic advantages, the country adopted the state policy of diverting transit traffic to the Russian seaports already mentioned above. As a result, "since 2013 a large part of Russian foreign trade cargo flows has been forwarded from the ports of Ukraine and the Baltic countries to the domestic ports" (Ivin, Goryacheva and Kurbatskii, 2020).

Turkmenistan: The country possesses enormous hydrocarbon reserves, especially natural gas, and is actively developing its railway infrastructure. The main problem is that Turkmenistan is very distant from the main consumers. Turkmen crude is shipped by sea to Baku, Azerbaijan or Makhachkala, Russia. Small volumes of Turkmen petroleum oils are shipped by tankers to Russian or Ukrainian Black Sea ports (via the Volga-Don canal) or to Baku and then railed.

5 Result and discussion

This part of the article describes main problems complicating rail transportation of crude oil and refined products from the Caspian region to Europe and the ways to resolve them and was mainly prepared based on the responses of the interviewees listed in Appendix A below.

5.1 Main problems

(1) Monopolism and intermediaries: All the railways in the region are state-owned and represent natural monopolies. All the respondents declined to talk about intermediaries openly but hinted that they (intermediaries) enjoy full support in high echelons of power of the Caspian states. (Lawrence et al., 2008) mentioned in this regard that "the unusually high share of revenues that appears to be going to intermediaries compared to actual service providers. …an estimated third of revenues goes to intermediaries. By contrast, in Europe and North America, freight forwarders typically earn three percent of revenues". This problem was reported by 15 out of 20 interviewees. Interestingly, some of them represent these monopolists or intermediaries;

(2) Growth of railway rates: Rates grow regularly, but crude oil prices do not. On the contrary, crude oil prices decreased since 2014 significantly, and so did oil companies' revenues. One of the interviewees noted in this regard: "Railroads are used to perceive oil companies as cash cows. This is no longer the case. Constantly raising rail rates, they work against themselves". Another shippers' serious concern is that, in their view, a bigger part of railroad revenues has to be invested in the improvement of rail infrastructure and rolling stock, but this is not happening. 17 out of 20 interviews informed about this problem;

(3) Obscure railway rate-setting policy: As one of the interviewees mentioned, "In a perfect world, the quality of services and the rail rates for the transportation of oil and products should discourage oil producers from using alternative modes of transport. In reality, two companies from the same region often receive different rates to the same destination. This situation forces oil producers to look for alternatives". The same amount of respondents mentioned this problem (17 out of 20);

(4) Decrease of rail volumes of bulk oil cargoes: As mentioned above, these volumes have been decreasing over the last years. As a result, it is becoming more difficult to negotiate reduced rail rates for regional shippers, and this has become a serious concern for all the interviewees (20 out of 20);

(5) Strong influence of the political situation on transportation routes: Expectedly, the respondents refused to comment on this point even though some of them (12 out of 20) hinted at difficulties with rail shipments to

Europe via the Ukrainian territory since 2014 when the Russian-Ukrainian conflict began.;

(6) Difficult weather conditions of the Caspian (up to 90 days per year on average): Even though this problem is natural, it still creates a lot of problems for shippers. Adverse weather conditions (sea storms) often prevent departures of tankers, which lead to violations of railcars delivery schedules, large downtimes, etc. This problem was reported by 10 out of 20 interviewees;

(7) Significant losses when emptying rail tank cars: Talking about this problem, the respondents (10 out of 20) admitted that it is mostly caused by negligence and the use of rail tank cars without heating systems or with defective heating systems used in winter periods.

Figure 4 below provides the graphical representation of the information described in this paragraph.

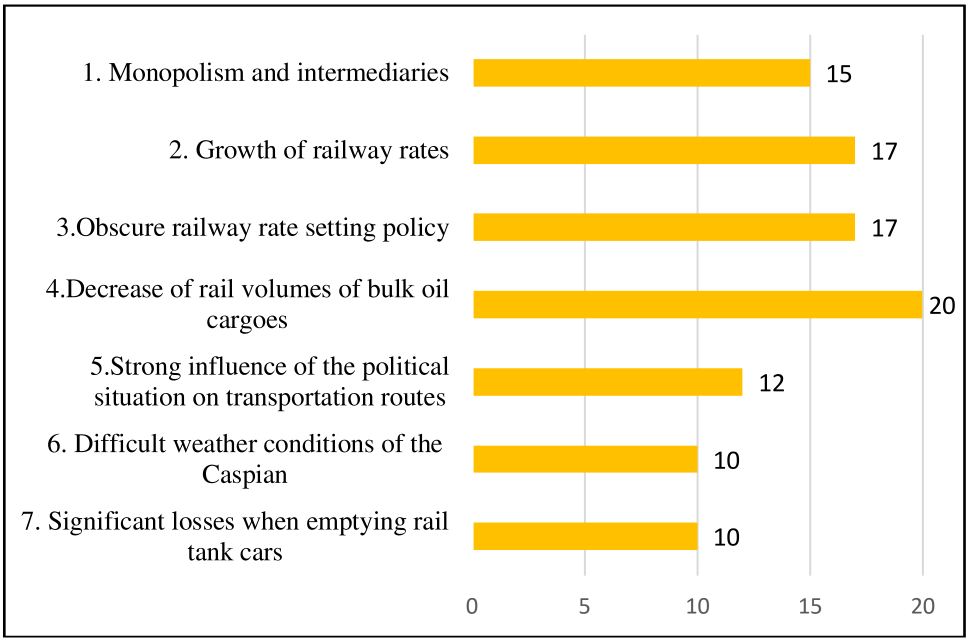

Figure 4 Main problems and the number of interviewees who reported them
Source: own construction

5.2 Ways to resolve problems

The interviewees suggested the following ways to resolve the problems listed above:

(1) Transition from transport to logistics corridors (a logistics corridor is the second stage of corridor development where establishing physical links to an area are accompanied by the harmonisation of the institutional framework): Most of the respondents (14 out of 20) actively supported this idea. Their common vision is that joined efforts of shippers, railway and port administrations and national governments can improve the situation substantially;

(2) Actual introduction of a competitive freight market: There was a consensus that this is a long-awaited and largely belated measure, which can remedy the situation greatly. 15 out of 20 respondents supported this idea. Another consensus was that the respondents do not expect this measure to be implemented soon though the delay with its introduction is damaging for the regional economies.;

(3) Proactive position of shippers: 11 representatives of oil companies and shippers complained that oil producers and shippers have no unified and proactive position. This is not a problem for big oil companies, which are strong enough to defend their interests. However, smaller companies and shippers suffer, so they should unite their efforts to improve their situation;

(4) Support from the governments and the railway administrations: 15 representatives of oil companies and traders repeatedly stressed that oil prices are no longer of US$140 per barrel. In the situation when oil prices are mostly below US$60 per barrel, it is now the turn of regional governments and railway administrations to support the oil shippers;

(5) Strong influence of the political situation on transportation routes: the solution to this problem is the prerogative of politicians. Respondents generally declined to comment anything else on this point;

(6) Difficult weather conditions of the Caspian: The respondents consider this circumstance as acts of God and do not consider this problem as a major one because the overall transit via the Caspian Sea is relatively small;

(7) Reduction of losses: This measure is obvious and was just mentioned. In general, the interviewees do not consider this problem as a serious one.

The respondents were generally less active in discussing solutions to the problems. Two main reasons may explain this: (i) the current situation is the most favourable for some of them and (ii) all of them are in one, or another way are bound by confidentiality obligations and cannot discuss every matter related to their work.

There is no graphical representation of the problems' solutions because all the interviewees refused to discuss point (5) as well as anything related to politics, and points (6) and (7) caused very little interest on their side.

Initially, the intent was to present the problems and the ways to resolve them in a tabular form. However, this way appeared to be inconvenient because the same measure is often a resolution to several problems. For example, measure (2) serves as a resolution to the problems (1), (2), (3) and (4). Importantly, the respondents insisted that a package of measures only can improve the situation.

6 Conclusions

There are several main points, which should be considered as conclusions to this article:

- Railway transportation of oil and refined products remains and will continue to be an important transportation option and, in some cases, the only possibility;
- The role of railway transport is extremely significant as a backup option for pipeline transport;
- The regional countries should commence the actual introduction of a competitive freight market and transition from transport to logistics corridors soon;
- Support from governments and railway administrations is particularly essential;
- The proactive position of shippers in the form of a transport union or association can help smaller oil companies and independent shippers.

The author of this article acknowledges the limitations of his research, which are caused by this market's private and confidential nature. This circumstance forced the interviewees to observe strict professional confidentiality obligations and self-censorship. The research's strengths include the scientific novelty of the topic, receiving first-hand information from the market players directly and the importance of the topic for European energy security. There is certainly a need for more research on the topic, and the author is planning to study it in more detail.

Research limitations

Limitations of this research are related to the following:

- Sample size: The situation is that the overall number of market players is limited. Another consideration is that this is qualitative research where the sample size is generally less relevant than in the quantitative type of research;
- Self-reported data: This limitation was addressed through cross-checking the answers and using literature sources where possible;
- Private and confidential nature of this business: This nature causes the respondents' professional confidentiality obligations and self-censorship. This limitation was addressed through (i) strict anonymity of respondents and (ii) warning them from the beginning that they have to avoid any sensitive issues. As a result, the interview processes went quite smoothly.

The limitations above do not downplay the cognitive value of the research as they pertain to the subject matter of this article.

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Appendix A

List of interviewees

1. Head of transport operations, international oil company, operating in Kazakhstan;
2. Senior Business development manager, Russian oil trading company;
3. Vice-president for operations, Russian transportation company;
4. Head of export operations, a small Russian oil company;
5. Representative, Kazakhstan Association of Carriers and wagon operators;
6. Head of the export department, a Kazakh oil company;
7. Senior specialist, transportation and marketing department, a Kazakh oil company;
8. Deputy director-general for commerce, a Ukrainian oil company;
9. Transport manager, international shipping operator;
10. Commercial manager, a Lithuanian oil company;
11. Director general, Russian oil trading company;
12. Transport manager, a Kazakh oil company;
13. CEO, Azeri oil trading company;
14. Manager, Turkmen oil company;
15. Head of division, Azerbaijan Railways;
16. Representative in Azerbaijan, Georgian oil trading company;
17. Transport manager, international oil trading company;
18. Head of the transportation department, European oil company, operating in Kazakhstan;
19. Manager, oil market intelligence agency;
20. Manager, Russian Black seaport administration.

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MARKETING AND LOGISTICS: FEATURES OF FUNCTIONING DURING THE PANDEMIC

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Abstract: The need to revise existing approaches and business strategies in logistics was identified in connection with global imbalances in the world economy against the background of the fight against the COVID-19 pandemic. The theory of the organization of marketing activities is considered, a critical analysis is carried out in order to determine the main components of the interaction between marketing and logistics. The lack of a unified approach to organizing effective marketing activities and its interaction with logistics during the COVID-19 pandemic is emphasized. The main components of the marketing concept of doing business have been substantiated. The functional areas of interaction between marketing and logistics in the world during the COVID-19 pandemic have been determined. The classification of the key factors that influenced the transformation of logistics activities in the world has been substantiated. Structural and logical analysis revealed the main trends in the development of the logistics industry in the world. The main tools of scenario economic and mathematical modelling are used to determine the features of the functioning of marketing and logistics during the COVID-19 pandemic and to determine the main trends in their development and interaction. Unlike existing approaches, the proposed one takes into account all the critical influencing factors in the context of COVID-19 and allows you to determine the prospects for the next few years. The main results of the research can be applied in the practical activities of organizations in the formation of development strategies and marketing concepts.

1 Introduction

Features of doing business in the context of global transformations under the influence of various factors, both internal and external, due to the need to ensure the effective operation of organizations and companies around the world. The formation and implementation of strategic areas related to logistics are the main elements of marketing activities of most global companies. Foreign companies apply logistics and goods marketing strategies, supply chain management concepts at the national, regional and global levels. Today, the activities of many companies and organizations, as never before, are confirmed by the impact of a number of different factors. On the one hand, the analysis of the main trends of changes in various markets shows a steady increase in competition and the intensity of competition in all sectors of the world economy during the COVID-19 pandemic. However, the exacerbation of global imbalances caused by massive constraints in the fight against the spread of the pandemic poses strategic challenges to companies around the world, which are associated with the desire to gain a stable and long-term advantage over competitors with the need to achieve the highest efficiency. On the other hand, many companies and organizations are subject to the daily resolution of contradictions due to the imperfection of existing economic models, which are expressed in the specifics of the organization of their activities, taking into account modern restrictive measures related to the COVID-19 pandemic. In modern conditions, despite the existing measures to limit the economic activities of companies and organizations in a pandemic, the main goal for each company is to meet consumer needs to maximize profits by promoting their products using an effective marketing concept. In a pandemic, the focus of companies and organizations in the global market is on ensuring the effective use of existing capacity, taking into account key factors of influence.

This approach ensures companies' financial stability and long-term development, despite the existing limitations and the reduction in the number of consumers with the intensive development of innovative technologies. Management of companies arises when top management decides when a new order of relations is developed to overcome the problematic situations associated with the restrictive measures of the COVID-19 pandemic when new links are established between structural units related to organizational structure modification. One of the most effective tools (methods) of company management in modern realities are logistics and marketing. However, the functional interaction of marketing and logistics in a pandemic is quite relevant and requires more detailed research. It should be noted that comprehensive practical studies addressing the interaction of marketing and logistics in a COVID-19 pandemic are insufficient, as there are no theoretical and methodological aspects to identify major trends in marketing and logistics, which requires more detailed study and in-depth study. These aspects are a key prerequisite for a more detailed study of the main aspects of marketing and logistics' functioning in a pandemic. The relevance and practical need to determine the main features of the interaction of marketing and logistics and the lack of developed scientific and methodological approaches to the study of this issue predetermine the study's main purpose and key objectives.

The processes of globalization of the world economy increase the need to find innovative ways and forms of the business organization under the influence of restrictive measures of the pandemic. These processes significantly complicate the relationship between the participants in production, distribution, and exchange processes due to a number of systemic changes and trends in the world economy, which requires the application and use of more innovative approaches to management. Logistics is no exception and requires the use of innovative tools in their activities. In modern conditions, the interaction of marketing and logistics in a pandemic is due to a holistic process: production-supply-distribution-sales. However, despite the above, the transformation of marketing under the influence of significant factors due to global imbalances caused by the pandemic is quite acute.

1.1 Marketing and logistics: theoretical aspects of functioning and features of interaction

The theoretical aspects of the organization of marketing activities are disclosed in scientific works [1-6], which examine the historical moments of the formation of marketing as a key element of the company's strategic management. It should be noted that this approach is fundamental and laid the first steps in the development of marketing as the main set of elements that ensure the interaction of all structural divisions of the company in order to maximize the financial result. Despite the formed theoretical aspects, which consist in the formation of a simple marketing complex: product, price, sales and offer, it should be noted that these approaches do not focus on the need to analyze factors that can significantly affect the marketing mix, which is unacceptable in modern conditions of a pandemic and requires more in-depth research.

Analyzing the scientific literature and research in the field of marketing and the formation of its key components, it is worth highlighting the works [7-10], which, in contrast to existing approaches, consider the peculiarities of organizing the marketing mix taking into account the time factor and offer more advanced approaches that include such elements, like: product, price, sales, offer and environment.

The presented approaches are fundamental in the field of marketing development, since they expanded the standard set of key components and made it possible to take into account the factors that can influence the process of the company's functioning. However, this approach does not consider the peculiarities of the interaction of marketing and logistics as an integral mechanism, which requires further research. It should be noted that the modern market does not stand still and is subject to constant and continuous transformations under the influence of various global factors, which therefore causes many companies around the world to constantly develop and improve their mechanisms and approaches in promoting their products and brand of the company by transforming marketing elements in order to increase consumer loyalty: the implementation of online catalogues, online delivery and optimal logistics.

Maintaining competitiveness, forming and increasing competitive advantage, thereby ensuring a sufficiently high level of profit in the context of the COVID-19 pandemic, is possible only by applying in practice the concept of marketing, which allows satisfying the demands and needs of consumers in a combination of quality and price, and logistics in terms of optimizing commodity and material flows [8]. It should be noted that the main issues of interaction between two concepts of company management, which have proven their effectiveness in a free market - marketing and logistics - have recently received increased attention, as evidenced by a number of publications in the scientific literature.

Many domestic and foreign scientists [7-12] covered the issues of interaction between marketing and logistics, and the results of their integration in the activities of companies, to one degree or another, in their works. However, the majority of authors consider marketing and logistics as independent areas of production and economic activity, closely related to each other. Based on this, it is worth noting that in the scientific literature, special attention should be paid to the work of a group of scientists such as: [10-12], who expanded the marketing complex taking into account all modern trends, which includes: product, price, promotion, place sales, environment, people, process.

The presented approach is the closest to modern realities, but it does not consider the conceptual features of the functioning of marketing in the world and its interaction with logistics in a pandemic, which determines the relevance of the research topic and requires a deeper study. It should be noted that in the context of the pandemic, many companies around the world were placed in a very strict framework, which was based on strict restrictions on activities in order to reduce the social distance of the population and minimize the risks of the spread of the COVID-19 pandemic and did not allow full-fledged activities, which in turn affected the financial stability of both an individual company and the global economy as a whole. Based on this, it is worth noting that the transformation of the world market has led to a revision of the existing management approaches in order to improve and optimize those using innovative technologies and tools, which is reflected in the areas of marketing and its interaction with logistics.

Using marketing tools, a company can determine "its" consumers, namely who they are, what their needs are, in what quantity and what quality goods they need, what is a substitute for these goods and, in the end, receive recommendations on how to build the company's activities in order to tie them to it consumers. Logistics tools are designed, first, to organize the movement of commodity and material rationally flows at the enterprise, which will allow you to receive the timely delivery of finished products to the consumer at the right place, at the right time, in the right quantity and quality with minimal costs. As you can see, both of these tools in the organization's activities solve different functional tasks and in no way replace each other. Rather, on the contrary, only their joint use can guarantee the efficiency of the enterprise [8-9].

Although, in essence, both marketing and logistics companies can use in their activities independently of each other. So, using only a marketing concept, a company will not be able to effectively organize the promotion of its goods on the market since unresolved logistics issues of delivery, transportation, storage of goods can hinder this. In modern conditions of market saturation and global transformations caused by the COVID-19 pandemic, when the traditional motivational criteria of the consumer (quality and price of goods) fade into the background, these issues become almost decisive when the consumer makes a purchase decision. A similar situation develops when the marketing concept is ignored in the company's activities, since the logistics tasks cannot, in turn, be effectively implemented without marketing support. Thus, marketing and logistics cannot be separated from each other, since together they form the general conditions and policies of the enterprise's production, supply, and sales activities. Skilful use of both concepts simultaneously gives a much greater synergistic effect than the use of each concept separately [10-12].

There is a lot of discussion about the interaction of marketing and logistics. It is in the framework of clarifying the issue, hierarchy and priority of concepts, which inevitably leads to a dead end. The issue of delimiting the areas of competence of marketing and logistics is especially acute in conditions of limited company resources, when the choice of which of the two concepts should be preferred? Especially in extreme conditions such as activity restrictions and global quarantine measures. It is worth noting that an answer to this question can be obtained by analyzing the functional areas of the collision or intersection of interests of the two concepts and determining on its basis the mechanism of their interaction, which are presented in Table 1.

Table 1 Structuring the functionality and features of the interaction of marketing and logistics in the context of the COVID-19 pandemic

Marketing concept element	Functional features		Interaction area
	marketing	logistics	
Production	determination of subject specialization and assortment structure of production;	identification of potential sources of supply;	packing goods
	determination of the characteristics and physical properties of the goods;	rational organization of production;	
	improving the quality and competitiveness of goods	marketing policy management	
price policy	choice of strategy and method of pricing	reduction of costs in distribution channels	setting a competitive price
sales policy	market segmentation and selection of the target segment;	rationing of stocks of finished products;	conditions for the availability of goods to the consumer; formation of a distribution system; the choice of channels for the distribution of finished products; sales analysis; service maintenance
	search for potential consumers;	creation of a storage system, cargo handling;	
	demand generation and sales promotion;	selection of an effective option for transporting products to the end consumer;	
	study and forecasting of demand; sales forecasting	development of cost estimates for sales and control over its observance	
Information system	formation of a marketing information system;	formation of a logistics information system;	justification and organization of information support for the sales system
	marketing research	organization of effective management of information flows	

The modern market is significantly different from what existed 5 years ago. Today, the consumer is a direct participant in the value chain, which is reflected in the individualization of products and their globalization into the global space, taking into account all the restrictive measures of the pandemic. For the manufacturer, it becomes profitable to serial production, focused on the individual consumer with the possibility of sales taking into account modern realities.

The process of selling products has also become more complicated, which today cannot be imagined without CRM order processing systems, online platforms for ordering and delivering goods with a whole range of other logistics services. The application of the logistics concept in these conditions allows us to meet the individual needs in the quantity, timing and place of delivery of each consumer, standardizing them in a certain way.

Historically, marketing began earlier than logistics. The preconditions for the emergence of the concept were associated primarily with unorganized competition, ignoring the needs of the consumer and, as a consequence, with the difficulties encountered by manufacturers with the sale of goods. The use, at that time, of marketing contributed to the regulation of the relationship between the seller and the buyer, between the manufacturer and the consumer. In today's pandemic, it is no longer possible to achieve serious competitive advantages only through the use of marketing. It is no longer enough to identify potential consumer demand with the help of marketing tools; it is necessary to turn it into real demand, which must be satisfied in a timely manner. The fast and accurate delivery of goods to the consumer, which is possible only with well-established logistics, becomes one of the competitive advantages and ways of gaining customer loyalty.

Companies that have built their activities on the basis of a marketing concept sooner or later come to the need to create a logistics system that will optimize many processes, especially taking into account the global constraints associated with the COVID-19 pandemic. By improving the quality of logistics processes and increasing the depth of its integration with other management functions, the company gains additional competitive advantages, allowing it to occupy a more stable position in the market.

1.2 Logistics in the world: the main prospects for development and current trends

The pandemic has caused significant financial losses to the world economy and has hit hard on logistics and supply of raw materials and finished products. However, it is worth noting that the ability to adapt quickly to changing circumstances can help many companies recover quickly after a pandemic.

The crisis caused by global uncertainty, panic, and unpreparedness for drastic changes in the world economic structure initiated an imbalance in freight flows due to changes in demand, suspension of production organizations, and certain restrictions.

In view of the current situation, the governments of most countries, together with international companies, have set themselves the main tasks of stabilizing economies and supporting their continued operation and the stability of supply chains. It is worth noting that the global imbalances in the world economy exacerbated by massive restrictions related to the pandemic, which caused chaos and panic among the countries of the world, the goals aimed at stabilizing the economy and its long-term development remained necessary and relevant [13].

The pandemic has significantly transformed most companies around the world. It should be noted that the logistics industry has also transformed and will no longer be the same as before.

Many changes have made the companies cardinally to revise the way of activity and peculiarities of functioning in order to fulfil strategic tasks, namely: production of goods, their promotion, drawing up a pricing policy and further logistics, taking into account the need to optimize existing business processes of companies and maximum automation to reduce physical contacts of people and compliance with quarantine restrictions and sanitary standards. After the spread of the pandemic subsided, many companies began to conduct a detailed analysis of the current conditions of operation in the market, identifying key trends, studying consumer behaviour and their main preferences for the implementation of maximum personalization and retention of the customer base, which is quite important in the face of increasing competition in world markets.

It should be noted that the world economy during the pandemic was significantly dependent on logistics on a global scale. This fact contributed to the transformation of organizing logistics activities in the world and its mass collaboration to survive in the market and strengthen its position by offering relevant services using modern digital technologies. In the context of a post-demotic peak in the global economy, it should be noted that it is the collaboration of logistics companies into a single complex that will make it possible to become the most stable and effective drivers for the subsequent promising development and growth in the global scale of logistics services.

However, the presented transformations and collaborations cannot be imagined without substantial support and strategic interaction of other equally important market players in order to develop a comprehensive action plan to combat the consequences of the crisis phenomena caused by the coronavirus pandemic. This combination of efforts has also significantly influenced the building of partnerships and the revision of responsibilities for them, taking into account current trends that significantly impact the field of logistics services.

Based on this, it is worth arguing that trends will affect all areas of companies, especially in the field of logistics, regardless of the situation in the world, which are presented in more detail in Table 2.

Table 2 Classification of trends that affect the logistics of companies during the COVID-19 pandemic

Main trends of influence	Characteristics and features of the functioning of logistics
Dumping in the logistics market	The intensification of the struggle for the customer leads to the emergence of price dumping in the freight market, as the number of goods decreases and transport is idle. Many companies will not withstand prolonged dumping during a pandemic.
Tough competition	The pandemic has intensified competition in the field of logistics services, which in turn has forced small and some medium-sized companies to leave the market. This aspect indicates that a series of bankruptcies, mergers and acquisitions will begin in the near future.
Development of collaborations, cooperation, integration of services	Logistics and service companies are starting to collaborate, develop unique complex offers for customers and, as a result, strengthen their joint positions by combining their services.
Increased demand for repair and maintenance services for vehicle fleets	Refusal to renew the vehicle fleet due to the rise in the exchange rate and the pandemic is observed in 90% of logistics companies. This led to the growth of services related to the repair and maintenance of vehicle fleets.
Implementation of the latest IT technologies	During the pandemic, many companies decided to transfer all work to innovative IT platforms for logistics companies in order to exchange tariffs and rates.
Development of domestic cargo transportation and supply chains	The pandemic gave impetus to the development of the domestic product, the development of industries within the country. A significant decrease in freight flows from other Asian countries and the threat of closing borders with China in the event of the next wave of a pandemic led to the fact that some of the resources, goods, products that were previously purchased there, manufacturers began to produce in their country.
Outsourcing development	The trend of outsourcing non-core processes and services is gaining momentum in trade.
Contactless courier delivery	Contactless delivery - taking care of the health of senders and recipients. The end consumer is offered the widest range of goods with contactless home delivery.
Development of parcel delivery by drones. Development of "autopilot" deliveries	This trend came from Asia as a continuation of the idea of contactless delivery. During the pandemic in China, most parcels were delivered "to your home" in this way.
Transfer of the majority of employees on a permanent basis to remote work	This will require optimization and automation of all business processes of the logistics operator.
Translation of all global logistics events into an online format	The trend for most events in the logistics sector in the online format will continue, because this format of meetings, negotiations, webinars, conferences has shown high efficiency.
Logistics companies must develop an anti-crisis plan	The experience of the crisis during a pandemic will determine the management of logistics companies to develop anti-crisis measures for organizations.

Based on the presented trends, which have a significant impact on the process of organizing logistics services, it should be noted that in order to get out of the crisis state of the logistics industry in all large countries of the world, state support measures are being actively implemented. It should be noted that, as a rule, support is provided to the public transport sector (railways, aviation, shipping, etc.).

However, government support can be provided to the commercial sector by introducing tax holidays, cancelling or reducing road tolls, and financial assistance to companies that have suffered large losses due to the pandemic. This support is very important if we consider road transportation, then there is a weighty help in reducing the cost of spare parts for vehicles by reducing import duties or tax rates for this group of goods. Very effective measures in some countries include a moratorium on fines (other than fines regulating road safety), abolishing the collection of tolls on federal highways, tax exemptions for the most vulnerable carriers, and suspension of lease payments without fines [13-14].

The provided support will allow this industry to significantly recover, revise its approaches to organizing effective work and build more sustainable development strategies, taking into account the main development trends in the world market and factors that have a significant impact. Consolidating the presented, it should be noted that in the modern world in the conditions of crisis, the phenomenon caused by a pandemic is quite important and relevant to build an effective marketing strategy with optimal interaction with the logistics industry.

2 Methodology

Peer Review Process

The transformation of the global financial market under the influence of the crisis phenomena caused by the COVID-19 pandemic creates massive uncertainty, which significantly complicates the activities of companies and the conditions for doing business. In order to determine the main aspects of the functioning of marketing and its interaction with logistics during the pandemic, tools for critical analysis of existing scientific approaches were used. For the formation of scientific and methodological aspects of the interaction of marketing and logistics, the existing approaches to the construction of marketing strategies with various sets of complex elements are considered. The presented allowed us to highlight the existing marketing concepts in the world with a different complex of elements, but they do not reveal the peculiarities of the interaction between marketing and logistics, which proves the absence of a unified scientific approach and requires a more detailed study. With the help of structural and logical analysis, the key trends in the development of the logistics industry are identified, highlighting the main trends in the development of the logistics industry in the world. It has been reported that determining the features of the functioning of marketing and logistics during the COVID-19 pandemic and determining the main trends in their development and interaction is conceptually necessary to use scenario economic and mathematical modelling with a step-by-step construction of development scenarios and construct a further forecast of future growth. The proposed methodology for the first time takes into account the factors of influence in the conditions of COVID-19 and allows you to determine the prospects for the next few years, according to the developed theoretical rules.

The main results of the study can be applied in the practical activities of organizations in the formation of a development strategy and marketing concept. The methodological and practical component was the indicators of the dynamics of the development of logistics services and marketing in the world during the COVID-19 pandemic. Scenarios of economic and mathematical modelling and forecasting have been developed that will make it possible to identify the key influencing factors that have a significant impact on the processes of organizing the marketing activities of companies around the world. The main results can be applied in the practice of many companies in the formation of the marketing concept and identification of the key links of interaction with the logistics industry.

3 Result and discussion

In modern conditions, there is an intensive development of certain sectors of the world economy under the influence of the crisis phenomena caused by restrictions on combating the pandemic. The development of logistics services and transport forwarding is taking place at a rapid pace. The growing demands of cargo owners, a high level of competition in the industry and relationships with the external environment require transport enterprises to search for new ways of development, search and use new approaches and tools to attract and maintain their customers. The need to develop the freight forwarding services market is obvious.

The transformation of the world market and global changes have clearly demonstrated the vital importance of the logistics industry. However, its impact on logistics companies differs depending on the types of goods transported and the industries served. Characteristics of the features of the functioning of the logistics industry in the world during a pandemic are presented in Table 3.

Table 3 Structuring the peculiarities of the functioning of the logistics industry in the world

Logistics type	Features of the functioning of the logistics industry
Road transportation	With the spread of the pandemic, the massive closure of factories and plants has led to a gradual decline in the relevance of transport as an element of logistics.
Air transportation	The cancellation of passenger flights also affected the cost of cargo delivery services, since most of them were previously delivered by passenger aircraft. This fact led to an increase in more than 2 times the cost of logistics services.
Shipping	Marine logistics, despite all the difficulties associated with restrictions, continues to work as usual. The logistics industry faced the problem of the lack of return containers, which affected the cost of export and its rise in price - it became necessary to organize direct flights for the supply of goods.
Rail transportation	The pandemic caused a decrease in the volume of railway traffic due to a global decrease in trade turnover, but the speed of delivery of goods increased, since there was no passenger traffic, which made it possible to increase the throughput of roads.

The global transformation of the global financial market under the influence of restrictions associated with the COVID-19 pandemic has radically changed the life of the world's population and the overall situation in the global and local markets. Around the world, there has been a significant reduction in production capacity due to the closure of borders between countries and the introduction of a self-isolation regime. The coronavirus pandemic has disrupted the familiar ties between manufacturers and consumers and has made major business changes for logistics companies. It should be noted that the spread of the coronavirus has dealt a serious blow to global logistics and supply chain security for raw materials and finished products. The aggravation of the crisis in the world economy caused a significant imbalance in freight traffic associated with changes in demand, the suspension of production and the imposed restrictions. In this regard, problems with the highest priority in maintaining the continuity and strength of supply chains have become the priority and most significant for the governments of states and international organizations.

It should be noted that despite the aggravation of the crisis in the world associated with the COVID-19 pandemic, the marketing activities of many companies and organizations were a key priority in ensuring uninterrupted work, an effective promotion system and logistics organization. It is important to note that the supply chains continued to function despite the restrictions, and the supply of FMCG products did not stop [14]. The crisis clearly demonstrated the vital importance of the logistics industry and made it possible to identify the key issues that need to be addressed when shaping a sales, management and logistics strategy. The transformation of the world market and individual industries also led to significant changes in logistics activities, which led to a revision of existing approaches to organizing logistics with the need to consider influencing factors. However, this transformation significantly complicated the existing processes in the logistics of organizations around the world, which were caused by the fact that many were not ready for such changes. The main factors that influenced the transformation of the logistics activities of organizations in a pandemic are presented in Table 4.

Table 4 Classification of key factors that influenced the transformation of logistics activities in the world

Key factor	Features of influence	Result of transformation of logistics activities
Increased demand	The pandemic caused a sharp increase in demand for some categories of goods, and a drop in demand for others, which was not factored into the planning of logistics. This led to supply disruptions, unclaimed inventory and the need to optimize logistics processes.	When forming a company’s strategy for the promotion and sale of goods and services, it is imperative to forecast demand and optimize existing processes by means of their automation.
Lack of supplier diversification	Sharp changes in the global market also required quick adaptations of supply chains and logistics categories of goods. Many companies whose strategy depended on direct supply were forced to reallocate resources.	When forming a company’s strategy for the promotion and sale of goods and services, it is imperative to diversify suppliers in order to minimize risks.
Increased load on the organization of logistics	The increase in demand for certain categories of goods has increased the burden on logistics. Companies are faced with the need to reallocate resources and look for additional carriers. This load demonstrated the need to optimize logistics processes.	The need to optimize logistics processes with their subsequent automation in order to reduce the time for collecting orders and the time of delivery of goods.
The need to automate the business processes of organizations and companies	The inefficiency of the existing logistics processes was caused by a sharp increase in demand and the inability to efficiently manage the processes of interaction both within the company and outside it.	Revision of existing interaction processes within the framework of the organization of logistics with the automation of the process of analyzing the customer base and the volume of purchases with further consideration in the formation of the organization’s strategy.

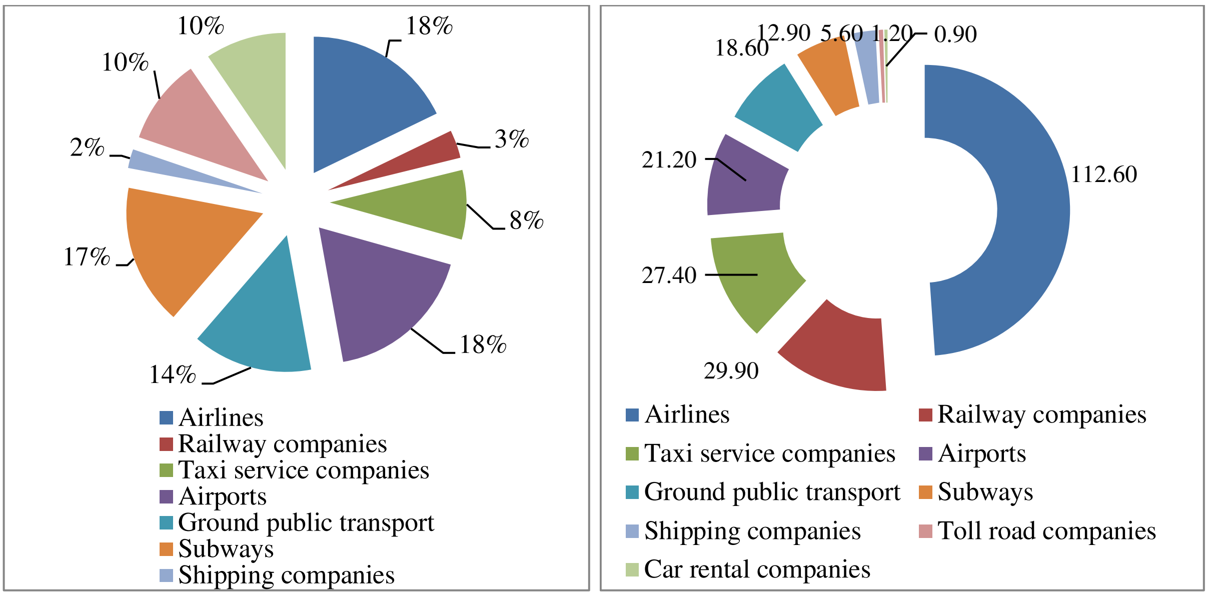
The main factors affecting the transformation of the logistics industry in the world are caused by the spread of the COVID-19 pandemic, which has dealt a serious blow to global logistics and the supply chain of raw materials and finished products. The uninterrupted functioning of this area of the world economy during the pandemic was possible only with the support of the governments of many countries and international organizations. Global imbalances in freight traffic around the world associated with a sharp increase in demand, the suspension of production and the introduction of organizational arrangements have significantly affected the economic growth on a global scale [15]. The presented imbalances and factors that caused the transformation of the logistics industry around the world led to the formation of the main strategic goals in this industry, namely the high priority of ensuring the continuity and strength of supply chains in all sectors of the world economy.

The trends in the logistics industry during the pandemic were associated with a decrease in cargo flow, both globally and locally, caused by the massive closure of borders of countries, shopping centers and stores, an increase in uncertainty and panic among the population, economic instability, an increase in currency quotes and a decrease in demand. and the purchasing power of a large proportion of the world's population. All presented trends are caused by drastic measures to combat the spread of COVID-19, which in turn caused the closure of many factories, factories around the world for quarantine in order to adhere to sanitary standards and recommendations of the Ministry of Health in this regard, there were no goods for transportation, and logistics also sucked out. Based on this, it is necessary to consider the main trends in the logistics industry during the pandemic, which served as the impetus for generating global chaos in the field of logistics services around the world.

The main factor that influenced the global logistics system was the aggravation of the crisis phenomena associated with the spread of the COVID-19 pandemic in China. In China, all types of transportation were affected: air, sea, rail, road, as a result of which the usual multimodal logistics schemes around the world were destroyed. However, this collapse did not last long and the Chinese authorities quickly stabilized the situation, which was ensured around the clock by many companies, logistics centers and organizations. Operators in the Chinese market have tried to respond flexibly to the situation, deploying emergency feeder services in difficult conditions. In general, in a short period of time, the supply chains were partially restored, which helped reduce uncertainty and panic in global markets [15].

However, not in all countries of the world, the stabilization of the logistics activity and the industry has come as well as in China. The economies of the EU countries are currently experiencing all the consequences of quarantine measures and interruptions in the supply of certain groups of goods. The movement of freight transport was not completely closed. However, there are certain restrictions since the number of infected people is not decreasing. These factors, on average, have already affected the economy of this group of countries, which is accompanied by a drop in economic growth by at least 40%. In many countries, there are support programs and strategic partnerships that make it possible to soften the impact of the crisis and economic downturn.

Based on the above, it is worth considering the share of losses of companies in the logistics complex in the world, % as a result of massive restrictive measures associated with the COVID-19 pandemic, which are presented in Figure 1.



A) in % B) in billion US dollars

Figure 1 The share of losses of companies in the logistics complex in the world due to the restrictive measures of the pandemic

From the presented structure of losses of companies in the logistics complex around the world, it is worth noting that airlines and airports suffered the most, which lost about $ 270 billion in 2019-2020 in the USA. The greatest losses were incurred by international air transportation, which is associated with the uncertainty of this industry since the flight schedule directly depends on the epidemiological and political situation in the separate countries. Also, this led to a decrease in cargo traffic, which is why many airlines have increased the cost of services by at least two times. A cyclical recession is observed in railway transportation. However, there are positive shifts that are inherent in this complex and associated with the fact that in many countries, transportation is stimulated by the provision of separate discounts and mutual partner settlements to maintain

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uninterrupted supplies, which is not insignificant in modern business conditions and ensures the effectiveness of the organization of marketing activities in this direction. It is worth noting that despite the closure of the borders in the segment of container transportation using sea transportation, there is slight growth and positive dynamics, but there are a number of uric moments in the direction of danger, which are associated with a reduction in the shipment of goods and goods to the East from Europe due to the complication of the situation with the pandemic. It should be noted that this type of logistics complex has historically always been volatile and uncertain due to the focus on imports. However, it is worth noting that during the period of the COVID-19 pandemic, the volume of maritime transport throughout the world has grown significantly, which will ensure a rapid recovery of previous volumes and economic growth of the industry before the crisis [16]. The very peak of the pandemic's activity in Europe was one of the key reasons for the cancellation of the exit of ocean-going ships from Southeast Asia, since it is impossible to process ship lots in European ports - this was the main reason for the presented share of losses in this direction.

The coronavirus epidemic has also affected trucking. Huge queues at the borders in almost all countries have significantly increased the delivery time of goods, thus reducing the volume of income received and reducing economic growth in this industry. The current situation has led to the need to reduce the frequency of departures of individual flights and rebuild routes. Due to the lack of transport, the cost of transportation increased almost 2 times, which is associated with the need for uninterrupted functioning, taking into account all sanitary standards and delivery times. All the factors presented will significantly complicate the process of doing business, and the massive restrictions associated with the pandemic made it necessary to search for new innovative approaches for organizing the logistics activities of companies. There are many factors that determine the need for the development of companies in the logistics industry during the spread of the pandemic, which are worth considering in more detail, which are presented in Figure 2.

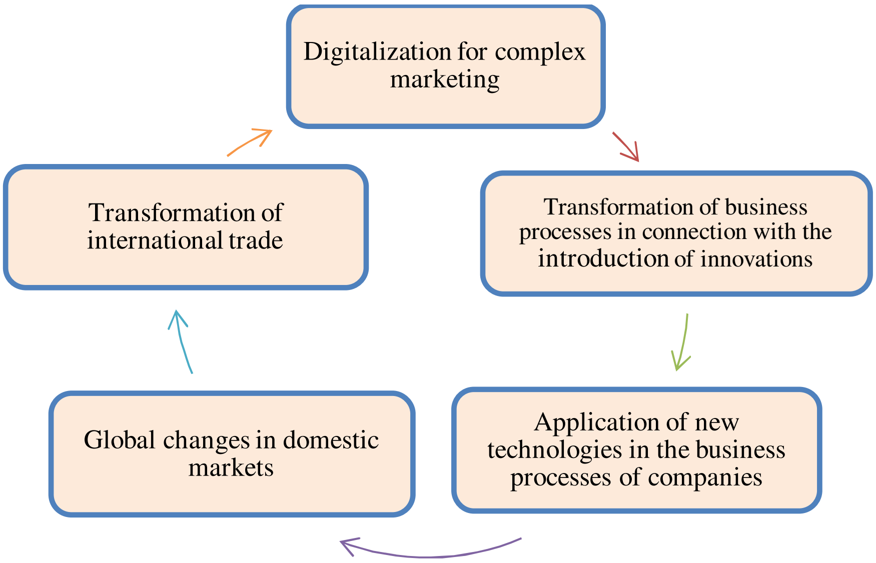


Figure 2 The share of losses of companies in the logistics complex in the world due to the restrictive measures of the pandemic

It should be noted that the presented factors make it possible to argue for the fact that the transport and logistics industry is going through a stage of transformation, which is determined by the emergence of new technologies and market trends. However, in recent years of the development of the global economic sector in the field of logistics, there has been no large-scale impact on the transport industry of political, economic, social, technological, environmental and legal changes [17,18]. In modern conditions, transport and logistics systems are constantly becoming more complex, and it is becoming more difficult to understand what should be paid attention to, especially in the context of aggravating crisis phenomena and the spread of a pandemic. Based on this, to determine the key trends in the functioning and interaction of marketing and logistics, it is worth using the tools of scenario economic and mathematical modeling. In the theory of economic and mathematical modeling, a mathematical function is used to determine development trends:

$$D_{xi} = f\big(M(x_i), L(x_i)\big) \tag{1}$$

Де, D_{xi} – modern trends in the development of marketing and logistics and their interaction in a pandemic, which are compared simultaneously with actions $\{X_i\}$;

$M(x_i)$ - the likelihood of a crisis event occurring when taking action $\{X_i\}$;

$L(x_i)$ - financial losses that are caused by the realization of risk, which with actions from multiple events $\{X_i\}$;

The spread of the pandemic worldwide, which is characterized by preventive and restrictive measures introduced in various countries of the world, contributes to the transformation of the logistics industry around the world. The spread of the pandemic around the world, which is characterized by preventive and restrictive measures that have been introduced in various countries of the world, which in turn contributes to the transformation of the logistics industry around the world. On this basis, in order to determine modern trends in the development of marketing and logistics, it is worth classifying countries by the level of the logistics efficiency index (LPI).

The Logistics Performance Index (LPI) is an interactive tool that is essential for benchmarking and classifying countries around the world by the level of development of the logistics industry and its efficiency. This index is a weighted average for the countries of the world by key parameters, such as the efficiency of customs, quality of logistics services, ease of organizing delivery and transportation, quality of logistics, tracking of shipments and deliveries of goods. According to countries' assessments, using this index, it is possible to determine with what ease and efficiency the logistics complex exist. The main scenarios of economic and mathematical modeling of modern trends in marketing and logistics and the peculiarities of their interaction during the spread of the pandemic on a global scale are presented in table 5.

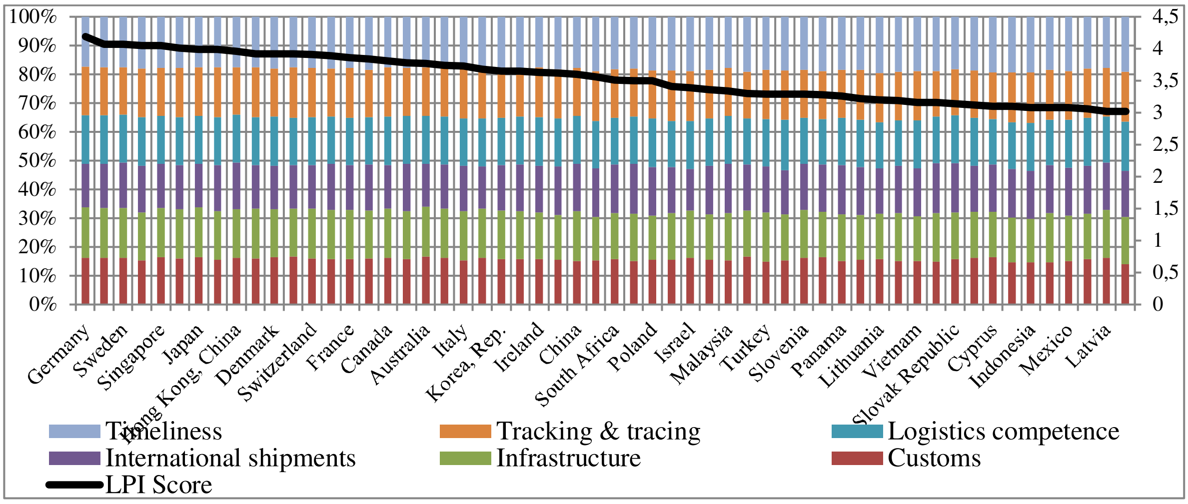
Table 5 Main scenarios of economic and mathematical modelling of modern trends in marketing and logistics and features of their interaction during a pandemic

Scenarios of economic and mathematical modeling of the level of logistics development	Graduation of the logistics efficiency indicator	Features of development and functioning
Optimistic development scenario	3.02-5.00	Intensive development of the logistics complex, taking into account the transformation of the world market under the influence of the pandemic and factors that have a negative impact on the functioning of marketing activities and its relationship with logistics.
Pesimistic scenario of development	2.51-3.00	The functioning of the logistics complex is accompanied by a number of global problems that have negative consequences and give rise to crisis phenomena in the activities of both individual companies and the industry as a whole.
Critical development scenario requiring anti-crisis management	2.00-2.5	Realized risks in the field of the logistics complex, both in an individual country and in entire regions, which require the introduction of support and the development of an anti-crisis partnership in order to reduce the proportion of financial losses that are caused by factors of macroeconomic influence.

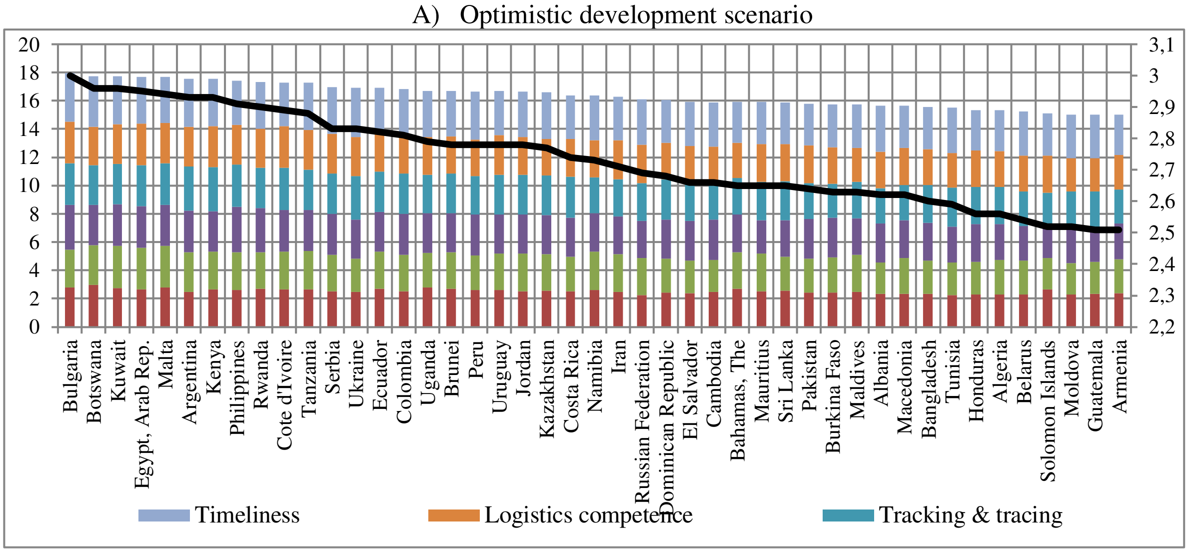
Logistics Performance (LPI) is a weighted average of a country for six key dimensions that will be used to classify countries by scenarios for the development and interaction of marketing and logistics during a pandemic [18].

The key parameters of scenario economic and mathematical modeling of trends in the development of marketing and logistics and the peculiarities of their relationship during a pandemic are the following:

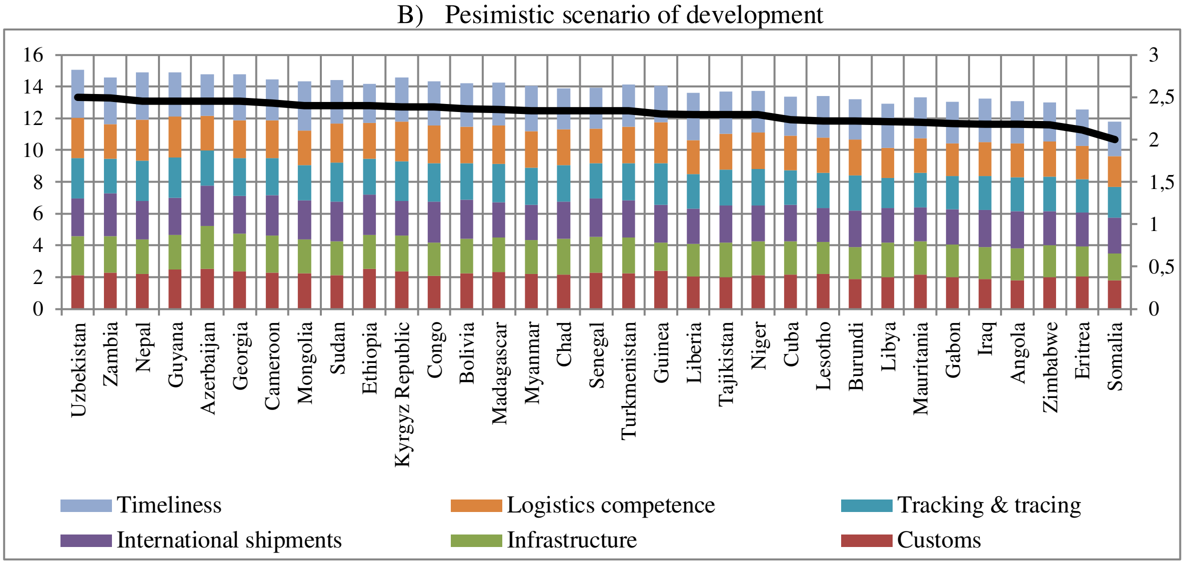
- The efficiency of the country's customs service (speed and availability of customs clearance of cargo transportation);
- Optimal and high-quality trade and transport infrastructure;
- Competitive pricing and ease of transportation;
- High professional training of employees of the logistics complex, which in turn allows to optimize the business processes of companies;
- Tracking tools for shipments and deliveries of goods and cargo;
- The quality and efficiency of delivery to the destination within the announced delivery time.



A) Optimistic development scenario



B) Pesimistic scenario of development



C) Critical development scenario requiring anti-crisis management

Figure 3 The main results of scenario modeling of the peculiarities of the functioning of marketing and logistics and their main interrelationships in a pandemic, in %

Based on the above, it is worthwhile to conduct scenario modelling of the features of the functioning of marketing and logistics and their main interrelationships in the current conditions of the spread of a pandemic. To do this, it is worth calculating the logistics efficiency index for all countries of the world and, based on the results obtained, classify each country based on which development scenario is most suitable for the ranges of indicators. The presented results of scenario modelling indicate that modern trends in the development of logistics complexes within the framework of the organization of the modern concept of marketing are characterized by the fact that in many countries, this development is carried out according to an optimistic forecast. This is because in these countries, the logistics efficiency index is in the range from 3.02 to 5, which is characterized by a high level of management and decision-making under the influence of factors caused by the pandemic. The main results of scenario modelling of the peculiarities of the functioning of marketing and logistics and their main interrelationships in a pandemic are shown in figure 3.

4 Conclusions

Logistics in modern business conditions is becoming a real organizational, technological and conceptual support for many companies and is the most effective tool for future development. It has been shown that logistics is a key instrument in the modern marketing strategy, without which it is impossible to manufacture and increase the company's capacity without positioning it and improving its competitive position in the world market. However, not all countries are characterized by the optimistic development of the logistics complex, which is evidenced by the fact that according to the pessimistic scenario of logistics development in the marketing complex, most countries are currently functioning. This group of countries is on the border between two scenarios, both optimistic and crisis, which depends on the effectiveness of management and the propensity to accept the level of risks that are caused by the pandemic. It is worth noting that the main results of the study of the dynamics of the development of marketing and logistics, as well as their interaction, as the main component of a modern company, indicate that in many countries now, the management of logistics is in a state of crisis, which is caused by a pandemic. However, to increase the volume of freight traffic in all countries, an adequate strategy for future development is needed, which includes an innovative marketing complex, which is not possible without logistics.

The theoretical and methodological aspects were developed to determine the interaction of marketing and logistics during the COVID-19 pandemic, which made it possible to substantiate the main components of the marketing concept for doing business, ensuring efficiency and financial stability of the organization. The features of the functioning of logistics on a global scale have been considered, which made it possible to substantiate the classification of key factors that influenced the transformation of logistics activities in the world. Based on scenario economic and mathematical modelling, the functioning of marketing and logistics during the COVID-19 pandemic is determined. The study's main results can be applied in the practical activities of organizations in the formation of a development strategy and marketing concept.

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ANALYSIS OF LOGISTIC PROVISION OF REVISIONS FOR CENTRAL STATE ADMINISTRATION BODIES

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Keywords: information system, technical equipment, supplier, innovations, logistics, management

Abstract: The implementation of information system modules in the conditions of state administration requires extensive project solutions. It differs from the implementation in the enterprise environment mainly by the nature of meeting the legislative conditions. Each implementation project is individual, and when designing its creation, it is necessary to take into account the content of an individual organizational components of the Ministry of the Interior of the Slovak Republic. This contribution aims to define the basic communication requirements that are placed on the information system for the operation of reserved technical equipment in the conditions of the Ministry of the Interior of the Slovak Republic. Knowledge of these requirements will allow setting the functionality of the information system for the operation of reserved technical equipment. The findings of the article and their application will save 20 - 40% of the total time, which will be appropriate to use to save on human resources or improve the activities of individual employees in the field of BOZP (occupational safety and health), operation of buildings, labour inspection. With proper predictive maintenance, the goal of reducing costs by 20% for individual more complex repairs, which are caused by neglect or omission of regular service, can be achieved. The application of research findings will have an impact on the reduction of accidents, accidents with long-term consequences or deaths caused by improper operation of technical equipment. The findings are appropriate to apply to employers with a number of facilities greater than 20.

1 Introduction

After the reform of the ESO, which was implemented by the Ministry of the Interior of the Slovak Republic, the provision of services in the area of professional inspections, professional tests and official tests was centralized. The centralization of procurement and subsequent implementation of services has brought a unified approach, which requires increased demands on central management. This requires tremendous dynamism in solving everyday tasks. As the largest employer in Slovakia with more than 50,000 employees located in buildings throughout Slovakia, the Ministry of the Interior of the Slovak Republic needs to ensure the reliable operation of individual reserved technical equipment. For facility operators who operate a larger number of facilities, it is important to know individual technical and reserved technical equipment and their individual parts. It is important to have their life cycle and all the activities performed within them documented and to evaluate the individual data gradually. In the economic operation of reserved technical equipment, it is important to know the investment costs of purchasing new equipment and the profitability of the operation of existing equipment. Not only energy costs but also service costs can be included in profitability. Service costs can be eliminated by properly knowing the data of the relevant technical equipment and preventing fictitious repairs carried out by unethical service suppliers. Many facility operators are in the pre-preparation phase of the implementation of the informatization of the system of operation of reserved technical equipment. This article will give the reader a concrete idea, which can be adapted to the operation of a smaller number of facilities, with a lower number of reserved and other technical equipment. The fulfilment of legislative obligations in the area of operation of reserved technical equipment must not be understood only as a formal fulfilment but as a way of ensuring the perfect technical condition of the relevant equipment. The main condition is to ensure occupational safety and health. The whole process of providing the services of professional inspections, professional tests and official tests requires perfect synchronization of individual steps. Manual monitoring of deadlines by individual security technicians located within the regions of Slovakia contributes to their burden. The most appropriate way seems to be to use the information system. The information system for the provision of professional inspections, professional tests and official tests is required to ensure comprehensive management of the operation of reserved technical equipment throughout Slovakia. In this article, we will deal only with the management of the information system for the operation of reserved technical equipment, which we consider to be a subsystem of the comprehensive information system of the Ministry of the Interior of the Slovak Republic.

2 Possibilities of software solutions for operation by operation of technical equipment

Today, there are a number of software solutions and applications that streamline various processes in companies. Each company is individual in its activity. In the field of occupational safety and health, uniform legislation contributes to the unification of activities, which exhaustively defines the obligations of facility operators. There are currently a number of software applications that include common requirements for enterprise information systems. SAP offers an integrated set of applications that support your end-to-end enterprise processes and help manage every part of your organization - employees, customers, products, expenses, finance and IT [1].

The implementation of a wide range of ERP systems in enterprises will cause significant changes in their operation and planning, organization and management of supplier processes. Adherence to the correct course of the implementation process will guarantee the integration of the information system from enterprises.

The SAP information system is mainly adapted to their specific conditions in various enterprises and state organizations, but the implementation process itself takes place uniformly according to the ASAP methodology in five phases:

a) Phase no. 1. Project preparations,
b) Phase no. 2 Target concept,
c) Phase no. 3 Realizations,
d) Phase no. 4. Preparation of a productive barrier,
e) Phase no. 5. Start of productive operation and support [2].

In this article, we will deal with the analysis of information system requirements. Requirements should be identified in the project preparation. Without their correct identification, process problems may occur in the next phases according to the ASAP methodology. Based on the requirements, we will re-evaluate which modules the information system should have at its disposal and what specifics the individual modules should take into account. The implementation of any ERP system represents a fundamental change in its functioning and organization of business processes. Only the correct course of the whole implementation process will guarantee the integration of IS with the enterprise [3].

The Ministry of the Interior of the Slovak Republic currently uses the services of the SAP system. Due to the number of buildings and the equipment of the buildings with a large number of reserved technical equipment, there is a need to adapt the individual SAP modules to individual requirements. The software should also take into account the individual differences of the individual organizations. The BTS software - Safety and Technical System, offered by the Besoft company, which has 20 years of experience in the field of occupational safety and health, is also known in the conditions of the Slovak Republic.

BTS software was created to simplify the work of its users. It was created on the basis of long-term experience and client requirements. Its structure consists of 14 modules. In its environment, it gathers valid legislative regulations, sample documentation, instructions, procedures and methods. It provides various tools for keeping records of employees, technical equipment, tracking deadlines, notifications and the like. The advantages are solutions for the elaboration of risk analyses, a system for verifying employees' knowledge and record keeping [4].

We currently live in the time of Industry 4.0. To apply the visions and ideas of this German platform, it is necessary to transform society's current thinking into thinking 4.0. The use of innovative elements of the 4.0 platform creates preconditions for the application of perfect informatization of the provision of a complex process of operation of reserved technical equipment, including the provision of their professional inspections and professional tests.

Industrie 4.0 describes a fundamental process of innovation and transformation in industrial production. This transformation is driven by new forms of economic activity and work in global, digital ecosystems: today's rigid and strictly defined value chains are replaced by flexible, highly dynamic and globally connected value networks with new forms of cooperation[5].

Industry 4.0 creates new requirements, which are placed not only on the production of new equipment but also on the operation of technical equipment. The impact of Industry 4.0 is gradual, and its pace depends on the economic and technical maturity of individual countries. In the operation of technical and reserved technical equipment in the conditions of the Slovak Republic, the question of their effective management with the help of information technologies, which can be directly or with the help of IoT Internet networks, arises. The aim is to effectively manage the life cycle of individual technical and reserved technical equipment. In addition to the issue of providing professional inspections, professional tests, official tests in the life cycle, we include issues of regular maintenance, as well as issues of profitability of operation of existing equipment. When implementing management processes, it is appropriate to use ISO standards, which also include the area of occupational safety and health - ISO 45001: 2016.

Industry 4.0 envisages the creation of new links between technology, man and control systems in the application of the most powerful IT systems in order to ensure the flexibility of the production process so that its output is a product that takes into account customer requirements in a broader sense [6]. Changes that occur in the industry also affect occupational safety and health. The environment created by Industry 4.0 should be gradually transformed into a non-industrial environment during the operation of technical equipment in the field of maintenance and revisions.

The changes that have taken place in the industry are reflected in the high automation of processes. This trend is currently referred to as the new Industrial Revolution Industry 4.0 [7].

These changes also need to be transformed into the automation of processes related to the provision of services of professional inspections, professional tests or official tests as well as maintenance services. An important condition is to take into account the activities and the different environment in which we provide.

Organizations operate in different environments, have different "patterns of behaviour", different conditions within the operation (globalization), which is reflected in the form of so-called "Dynamic decision-making". It is important that this decision is based on data that allow the analysis of all threats affecting the achievement of the desired result (objectives) but also the chances - opportunities for new solutions [8].

The National Labor Inspectorate on Industry 4.0 states that we live in a rapidly changing time, which we consider to be the beginning of a technological revolution. It sees this revolution as a consequence of the natural development of mankind. We recognize that the impact of Industry 4.0 is fundamentally changing the way of life in all areas. It points out that the response of state bodies must also be comprehensive, rapid and intelligent. It points to the importance of speed, flexibility and the ability to adapt to changing conditions and working environments [9].

Obtaining real-time information generated systematically through traceability technologies has been one of the key factors in the digital transformation of the industry, fostering global competition and EU supply chain innovation. [10,11]

In the manufacturing sector, it is where technology-based applications mainly allow companies to stay and position themselves in increasingly competitive markets, providing innovative solutions to the different challenges they face throughout the supply chain. [12]

Although the operation of reserved technical equipment does not directly affect the industry, it is important to make active use of elements of the logistic provision in the industry. The knowledge can be used to increase the efficiency of supply provision of services within the competence of the Ministry of the Interior of the Slovak Republic.

The issue of providing professional inspections, professional tests, official tests should be implemented with the idea of Industry 4.0. At present, there are a number of software solutions for the comprehensive provision of occupational safety and health (BOZP), but there is a need to adapt them to the conditions of the Ministry of the Interior of the Slovak Republic. When designing software solutions, the predictions of the development of Industry 4.0 in relation to the life cycle of technical and reserved technical equipment should be taken into account.

3 Basic legislative conditions for the operation of reserved technical equipment

The use of individual buildings is conditioned by the fulfilment of individual legislative conditions. These legislative conditions also include conditions arising from Act no. 124/2006 Coll. on occupational safety and health and on the amendment of certain laws as amended [13]. This law exhaustively determines the conditions for the safety of persons. The purpose is to ensure the protection of life and health of persons. Based on the implemented decree of the Ministry of Labor, Social Affairs and Family of the Slovak Republic no. 508/2009 Coll., which lays down details for ensuring occupational safety and health with technical pressure, lifting, electrical and gas equipment, and which lays down technical equipment, which is considered to be reserved technical equipment (VTZ), we know the employer's obligations in the operation of technical equipment [14].

In this article, we will deal with fulfilling the legislative conditions of safety of reserved technical equipment from the employer's point of view and his working environment. The conditions also apply to ordinary natural persons and households.

The individual reserved technical equipment is divided into [14]:

a) Pressure equipment of groups A, B, C. The exact qualification can be found in Annex no. 1 [14].
b) Lifting equipment of groups A, B, C. The exact qualification can be found in Annex no. 1 [14].
c) Electrical equipment A, B, C. The exact qualification can be found in Annex no. 1 [14].
d) Gas equipment A, B, C. The exact qualification can be found in Annex no. 1 [14].

At the Ministry of the Interior of the Slovak Republic, the operators of facilities [15] are:

a) Section of the economy,
b) Support Center Bratislava,
c) Support Center Trnava,
d) Support Center Nitra,
e) Support Center Trenčín,
f) Support Center Banská Bystrica,
g) Support Center Žilina,
h) Support Center Košice,
i) Support Center Prešov.

The security technician and the operator of individual reserved technical equipment is obliged to know which reserved technical equipment is operated, who is authorized to perform a professional inspection, professional test and official test. Also, who is authorized to operate and repair individual reserved technical equipment? The operator is obliged to record this obligatory knowledge. He is also obliged to provide individual types of training and refresher training. Employers with a low number of employees, facilities, and buildings are a relatively simple matter. The problem occurs with a higher number of facilities and employees. As we have already mentioned, the Ministry of the Interior of the Slovak Republic is the largest employer in Slovakia, it also has the largest number of facilities and buildings in the Slovak Republic. It is important to draw attention to the fact that the provision of services from external suppliers is part of the public procurement process, which is regulated by the Public Procurement Act no. 343/2015 Coll. on Public Procurement and on Amendments to Certain Acts [16]. Individual central state administration bodies are obliged to carry out public procurement before ordering individual services in the manner prescribed by legislation. Otherwise, they would break the law, or such action could have criminal consequences. Based on the above, it is important that individual state administration bodies have comprehensive records of reserved technical equipment when performing public procurement. The use of personal protective equipment is an essential part of protecting the life and health of employees. Obligations of the employer follow the legislation. According to the Regulation of the Government of the Slovak Republic no. 395/2006 Coll. on the minimum requirements for the provision and use of personal protective equipment, personal protective equipment is any equipment worn, held or otherwise used by an employee at work, including its accessories, if it is intended to protect the safety and health of the employee. [17]. For this reason, a thorough record is needed, which is necessary for the entire life cycle of personal protective equipment. For the application of the above regulation to the conditions of the Ministry of the Interior of the Slovak Republic, the regulation of the Ministry of the Interior of the Slovak Republic no. 53 on the provision and use of personal protective equipment is developed [18]. This regulation regulates the procedure of specific managers and the commodity centre in connection with the provision of personal protective equipment for employees of the Ministry of the Interior of the Slovak Republic. A basic internal organizational regulation solves the division of responsibilities and tasks of individual departments of the Ministry of the Interior of the Slovak Republic, and thus is the Regulation of the Ministry of the Interior of the Slovak Republic no. 39 on the organizational rules of the Ministry of the Interior of the Slovak Republic [19].

4 Methodology

Our goal will be to perform an analysis of the current state of logistic provision - Analysis of the services of professional inspections, professional tests and official tests in the conditions of the Ministry of the Interior of the Slovak Republic. Based on the performed analysis, we will propose the basic requirements that will be placed on the information system of logistic provision and control of professional inspections, professional tests and official tests.

The individual support centers and their organizational participation - real estate departments - are responsible for the operation of the reserved technical equipment. Through occupational health and safety (BOZP) and fire protection (PO) technicians, they send to the commodity center, which has the competence to issue orders for professional inspections (OP), professional tests (OS), repeated official tests (OUS). Based on the issued order, the service provider shall ensure the execution of the OP, OS, OUS and inform the operator and the safety technician about the results of the OP, OS, OUS. The facility operator confirms to the supplier the execution of the action of OP, OS, OUS. The following are the processes for performing an invoicing operation.

Table no. 1 shows the format of keeping the prescribed records of reserved technical gas equipment, which is registered by individual operators as well as BOZP and PO technicians. Its colour code is yellow. The individual prescribed data comply with legislative requirements [14]. They contain identification data such as the city, the street as well as the designation of the organizational unit of the location of the reserved technical gas equipment (VTZ-PL). The next part is specific data on reserved technical gas equipment, based on its classification according to legislative requirements [14]. Mandatory data are the name and type of reserved technical gas equipment, serial number, year of manufacture, power. Power Nm3 / h, power in kW, maximum operating pressure in [MPa], Group. In the next part, the interval of OUS, OP, OS is determined. Based on the determination of the date of the last OUS, OP, OS and the interval of OUS, OP, OS, the table uses the function to recalculate the subsequent OUS, OP, OS, and validity date of OUS, OP and OS in days. If the OUS, OP, OS is after the term of the validity end, the data in days is given in a negative statement. Based on the execution of OUS, OP, OS, the state of VTZ after OUS, OP, OS is recorded.

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Table 1 Records of reserved technical equipment - gas

Location data of VTZ - PL		Data on VTZ - PL								Interval of OP, OS and US in months			Date of the last OUS, OP and OS			Date of subsequent OUS, OP and OS			Validity of OUS, OP and OS in days			State of VTZ - PL after revision	Notes
City	Street	Name of VTZ - PL	Type of VTZ - PL	Serial number	Year of manufacture	Power Nm3/h	Power in kW	max. oper. pressure in [MPa]	Group	OUS	OP	OS	OUS	OP	OS	OUS	OP	OS	OUS	OP	OS	SBP – capable of safe oper. NBP – incapable of safe oper. OZP – decommissioned	

Source: The Ministry of the Interior of the Slovak Republic

Table no. 2 shows the format of keeping the prescribed records of reserved technical pressure equipment, which is registered by individual operators as well as BOZP and PO technicians. Its colour code is blue. The individual prescribed data comply with legislative requirements [14]. They contain identification data such as the city, the street, and the designation of the organizational unit of the location of the reserved technical pressure equipment (VTZ-TL). The next part is specific data on reserved technical pressure equipment, based on its classification according to legislation [14]. Mandatory data are name and type of reserved technical pressure equipment, serial number, year of manufacture, Volume in l, maximum operating pressure in [MPa], Safety factor (Vxp), Group. In the next part, the interval of OUS, repeated external inspection (OVP), external inspection (VP), pressure test (TS) is determined. Based on the determination of the date of the last OUS, OVP, VP, TS and the interval of OUS, OVP, VP, TS, the table uses the function to recalculate the date of the next OUS, OVP, VP, TS and the validity of OUS, OVP, VP, TS in days. If the OUS, OVP, VP, TS is after the term of the validity end, the data in days is given in a negative statement. Based on the execution of OUS, OVP, VP, TS, the state of VTZ after OUS, OVP, VP, TS is recorded.

Table 2 Records of reserved technical equipment - pressure

Location data of VTZ - TL		Data on VTZ - TL								Interval of TS,VP,OVP and OUS in months				Date of the last TS,VP,OVP and OUS				Date of subsequent TS,VP,OVP and OUS				Validity of TS,VP,OVP and OUS in days				State of VTZ - TL after revision	Notes
City	Street	Name of VTZ - TL	Type of VTZ - TL	Serial number	Year of manufacture	Volume in [l]	max. oper. pressure in [MPa]	Safety factor (Vxp)	Group	OUS	OVP	VP	TS	OUS	OVP	VP	TS	OUS	OVP	VP	TS	OUS	OVP	VP	TS	SBP – capable of safe oper. NBP – incapable of safe oper. OZP – odstavené z prev.	

Source: The Ministry of the Interior of the Slovak Republic

Table 3 shows the format of keeping the prescribed records of reserved technical electrical equipment, which is registered by individual operators as well as BOZP and PO technicians. Its colour code is green. The individual prescribed data comply with legislative requirements [14]. They contain identification data such as the city, the street, and the designation of the organizational unit of the location of the reserved technical electrical equipment (VTZ-EL). The next part is specific data on the reserved technical electrical equipment, based on its classification

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according to the prescribed legislation [14]. Mandatory data are name and type of reserved technical electrical equipment, number of electrical circuits, number of lightning conductor leads, power (kW), external influence, Group. In the next part, the interval of OUS, OP, OS is determined. Based on the determination of the date of the last OUS, OP, OS and the interval of OUS, OP, OS, the table uses the function to recalculate the date of the next OUS, OP, OS and the validity of OUS, OP and OS in days. If the OUS, OP, OS is after the term of the validity end, the data in days is given in a negative statement. Based on the execution of OUS, OP, OS, the state of VTZ after OUS, OP, OS is recorded.

Table 3 Records of reserved technical equipment – electrical

Location data of VTZ - EL		Data on VTZ - EL							Interval of OUS, OP and OS		Date of the last OUS, OP and OS		Date of subsequent OUS, OP and OS		Validity of OUS, OP and OS		State of VTZ - EL after revision	Notes
City	Street	Name of VTZ - EL	Type of VTZ - EL	Number of el. circuits	Number of lightning conductor leads	Power (kW)	External influence	Group	OUS	OP and OS	OUS	OP and OS	OUS	OP and OS	OUS	OP	SBP – capable of safe oper. NBP – incapable of safe oper. OZP – decommissioned	

Source: The Ministry of the Interior of the Slovak Republic

Table 4 shows the format of keeping the prescribed records of reserved technical lifting equipment, which is registered by individual operators as well as BOZP and PO technicians. Its colour code is grey. The individual prescribed data comply with legislative requirements [14]. They contain identification data such as the city, the street as well as the designation of the organizational unit of the location of the reserved technical lifting equipment (VTZ-ZD). The next part is specific data on the reserved technical lifting equipment, based on its classification according to the prescribed legislation [14]. Mandatory data are name and type of reserved technical lifting equipment, serial number, year of manufacture, Group. In the next part, the interval of OUS, OP, OS is determined. Based on the determination of the date of the last OUS, OP, OS and the interval of OUS, OP, OS, the table uses the function to recalculate the next OUS, OP, OS, and validity date of OUS, OP and OS in days. If the OUS, OP, OS is after the term of the validity end, the data in days is given in a negative statement. Based on the execution of OUS, OP, OS, the state of VTZ after OUS, OP, OS is recorded.

Table 4 Records of reserved technical equipment – lifting

Location data of VTZ - ZD		Data on VTZ - ZD					Interval of OUS, OP and OS in months			Date of the last OP and OS			Date of subsequent OP and OS			Validity of OP and OS in days			State of VTZ - ZD after revision	Notes
City	Street	Name of VTZ - ZD	Type of VTZ - ZD	Serial number	Year of manufacture	Group	OUS	OP	OS	OUS	OP	OS	OUS	OP	OS	OUS	OP	OS	SBP – capable of safe oper. NBP – incapable of safe oper. OZP – decommissioned	

Source: The Ministry of the Interior of the Slovak Republic

5 Result and discussion

Based on the performed analysis and comparison with the Decree [14], we found that the records of reserved technical equipment are prepared to contain all the necessary data for the security and technical service and the facility operator. It is also suitable to use this data for labour inspection. Records of reserved technical equipment are kept specifically for individual groups of reserved technical equipment. The tables are prepared using Microsoft Excel spreadsheet software. The shortcoming is the difficult communication between the supplier company, ensuring the performance of the OP, OS, OUS and the operator and individual BOZP technicians.

The use of the information system for the operation of the entire life cycle of individual reserved technical equipment appears to be an ideal model of the solution. The architecture and functional settings of the system should allow the implementation to enter the necessary data already directly to the facility operators and the supplier company. After the purchase and installation, the operator will ensure the registration of technical and reserved technical equipment in the information system. Subsequently, the system will recognize individual deadlines according to groups of reserved technical equipment. At the end of the life cycle, the inclusion and decommissioning of the equipment will ensure the registration of the equipment, while the decommissioning protocol will be entered into the information system for the purposes of registering to the archive.

The current supplier security system does not allow this. The data is entered into the tables by the operator or BOZP technician on the basis of a report from the OP, OS and OUS.

The advantage of entering data directly by the supplier company as well as from the scanned report on OP, OS, OUS is that it will provide the operators with automatic feedback. Direct feedback is important for urgent action in the event that deficiencies or serious deficiencies are identified. In the event of serious deficiencies, the system would automatically shut down the reserved technical equipment. In the event of serious technical deficiencies, this measure is necessary to protect the life and health of persons as well as the protection of property. The above information and instructions for the implementation of necessary and urgent measures are important, especially for the facility operator. They are also important for BOZP technicians and labour inspection bodies. Based on the list of exact deficiencies, the operator has the opportunity to urgently ensure the issuance of an order to eliminate deficiencies. It is also suitable if the system allows the storage of data on individual deficiencies of the reserved technical equipment as well as the financial costs of their elimination. The above data are needed to evaluate the profitability of the operation of the equipment and the decision to invest in new technical equipment.

Another requirement for the information system is to allow the labour inspection body to make changes to the system, especially in connection with the ordered measure for the protection of life, health and property.

Information flows (Figure 1) of individual actors of the information system:

Operators inputs: registration of reserved technical equipment, orders for the performance of OP, OS, OUS, orders for the performance of service and maintenance, shutdown of equipment, exclusion of equipment from the information system.

Operators outputs: information on performed OP, OS, OUS, instructions and regulations of the labour inspection body, performance of BTS from the BOZP technician, information on performed service, maintenance and condition of the equipment after service and maintenance. Report from the OP, OS OUS, instructions in case of finding deficiencies and serious deficiencies. Information on the inspection of professional competencies of revision technicians, authorized legal entities, and persons ensuring the operation of the reserved technical equipment.

Labour inspection body inputs: instructions and regulations to ensure the safe operation of the equipment. Information on the inspection of professional competencies of revision technicians, authorized legal entities and persons ensuring the operation of the reserved technical equipment.

Labour inspection body outputs comprehensive information on reserved technical equipment.

BOZP technicians inputs: performance of the activity of BOZP technician

BOZP technicians outputs: comprehensive information on reserved technical equipment. Information on the inspection of professional competencies of revision technicians, authorized legal entities and persons ensuring the operation of the reserved technical equipment.

Supplier companies providing service and maintenance inputs: information on the performed service, maintenance and condition of the equipment after service and maintenance.

Supplier companies providing service and maintenance outputs: report from the OP, OS OUS, instructions in case of finding deficiencies and serious deficiencies, order for the performance of service and maintenance.

Supplier companies providing OP, OS, OUS inputs: report on OP, OS OUS, instructions in case of finding deficiencies and serious deficiencies.

Supplier companies providing OP, OS, OUS outputs: order for the performance of OP, OS, OUS.

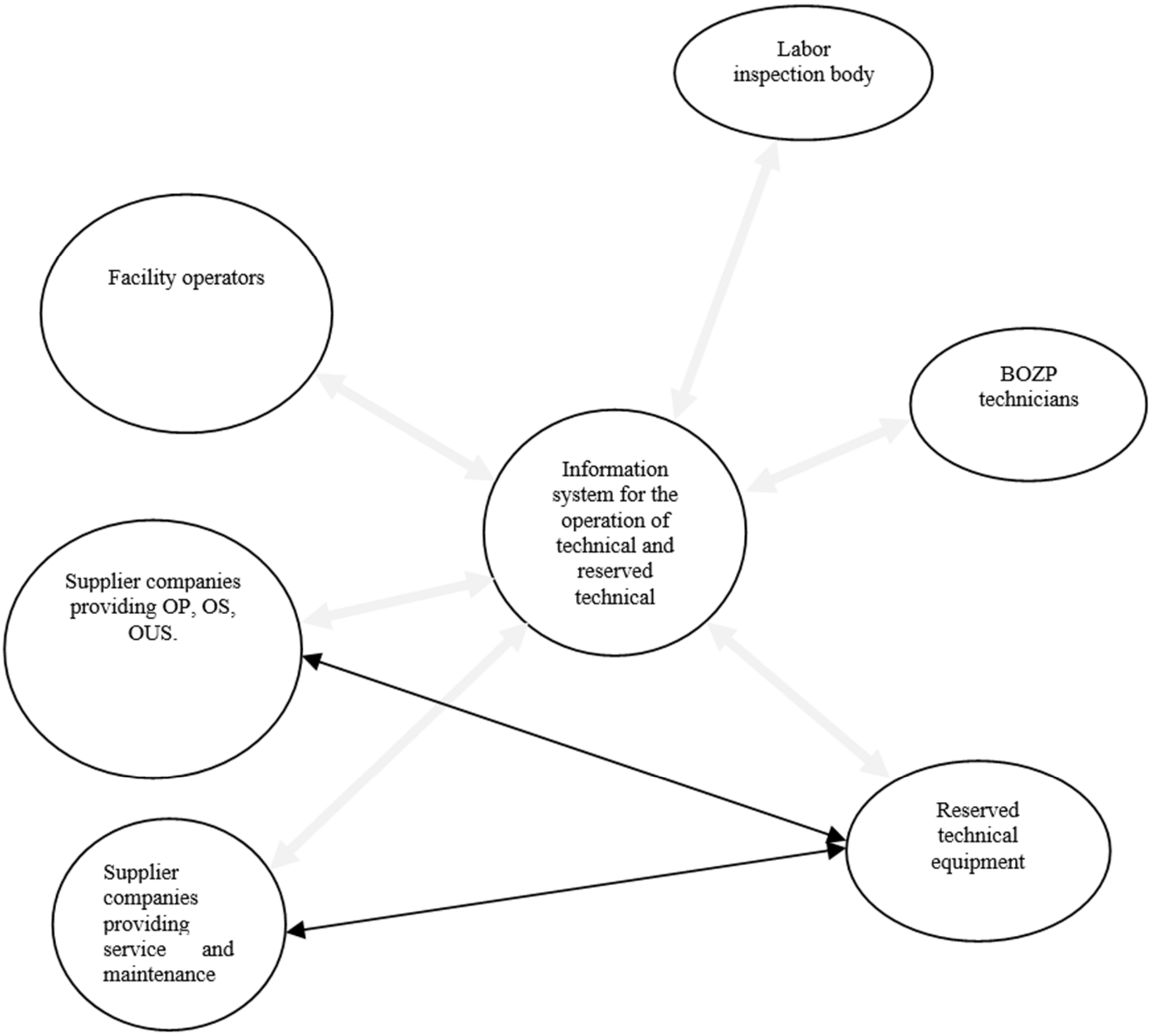

Figure 1 Logistics flow

The current state of individual reserved equipment does not allow their mutual communication. Their exchange for modern ones is gradual. The information system design that will manage the life cycle of individual reserved technical equipment should predict in advance the basic functional requirements of individual reserved technical equipment.

A new problem that will need to be solved in the future is the setting up of education and practice of the revision technicians themselves or authorized legal entities performing OP, OS and OUS. Modern types of reserved technical equipment controlled by artificial intelligence will require specific knowledge and experience of specialists.

6 Conclusions

The information system of logistic provision of the supplier method of OP, OS, OUS has its justification and brings time savings and the seamless transfer of information between individual actors in the field of occupational safety and health and labour inspection. The new innovative conditions brought by the time of Industry 4.0 need to be seen in the context of industry and other areas of life. We necessarily include the area of operation of individual technical equipment among these areas. The new reserved technical equipment will include 4.0 technologies. Therefore, the performance of individual processes, which facility operators will provide, must be coordinated based on current legislative requirements. The current provision method, which we analyzed in this article, meets the legislative requirements, but it is difficult to communicate between individual responsible employees. Coordination of activities using the information system will simplify and clarify individual logistic communication flows. It will enable individual responsible employees to perform activities in the field environment. Also the performance of urgent and non-repeatable actions in case of unsatisfactory technical condition or emergency condition of operated technical equipment. These solutions can also be used in enterprises that have larger numbers of buildings and employees. The application of ideas and theories arising from the Industry 4.0 concept requires a high level of knowledge, experience, skills and willingness to promote them. Therefore, the application of informatization in the process of operation of reserved and other technical equipment will require a gradual process of introducing the ideas and theories of Industry 4.0. The article points out the elimination of imperfections and negligence that can be caused by the human factor itself. This has a direct impact on the protection of people's lives and health. The article also points to the effective saving of human resources, as manual human activities will be replaced by the functions of the information system. The advantage is relieving employees from activities and their possibility of targeted work in field conditions during direct operation of technical equipment. When applying the knowledge, there will also be savings in postal and transport costs. Gradual application of knowledge in the operation of technical equipment using information systems will lead to changes in the current paradigms of operation and, last but not least, will have an impact on reducing operating costs.

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